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Fossil Fuel Fired Industrial Boilers - Background Information
Volume 2: Appendices

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Atlanta, GA

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Fossil Fuel Fired Industrial Boilers- Background Information Volume 2: Appendices

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Fossil Fuel Fired Industrial Boilers– Background Information Volume 2: Appendices

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

March 1982

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APPENDIX A

EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

The purpose of this study was to develop background information to support New Source Performance Standards (NSPS) for industrial boilers. Work on this study was performed by the Acurex Corporation from June 1978 until February 1980 and by the Radian Corporation after February 1980 under contract with the United States Environmental Protection Agency, Office of Air Quality Planning and Standards.

The following chronology lists the major events which have occurred during the development of background information for the industrial boiler NSPS. Major events are divided into three categories: (1) plant visits and emission testing, (2) meetings and briefings, and (3) reports and mailings.

I. Plant Visits and Emission Testing

July 28, 1978	Plant visit to DuPont in Wilmington, Delaware.
August 17, 1978	Plant visit to Caterpillar Tractor Company in Joliet, Illinois.
August 18, 1978	Plant visit to General Motors Corporation in Parma, Ohio.
September 11, 1978	Plant visit to Great Southern Paper in Cedar Springs, Georgia.
September 18, 1978	Plant visit to Babcock and Wilcox in Wilmington, North Carolina.

September 19, 1978	Plant visit to Cleaver Brooks in Lebanon, Pennsylvania.
September 20, 1978	Plant visit to Keeler Company in Williamsport, Pennsylvania.
September 21, 1978	Plant visit to International Boiler Works in East Stroudsburg, Pennsylvania.
September 22, 1978	Plant visit to Peabody Engineering Corporation in Stamford, Connecticut.
September 30, 1978	Plant visit to Mead Paperboard in Stevenson, Alabama.
November 14, 1978	Plant visit to Firestone Tire and Rubber Company, in Pottstown, Pennsylvania.
December 13, 1978	Visit for test presurvey to Rickenbacker Air Force Base in Columbus, Ohio.
January - March, 1979	Emission source testing at Rickenbacker Air Force Base in Columbus, Ohio.
February 21, 1979	Plant visit to Johnson Boiler Company offices in Ferrysburg, Michigan.
March 21, 1979	Plant visit to DuPont.
August 13, 1979	Plant visit to Holsum Foods in Waukesha, Wisconsin.
August 13, 1979	Plant visit to Libby, McNeil, and Libby in Janesville, Wisconsin.
August 14, 1979	Plant visit to Minn-Dak Farmer's Co-op in Whapeton, North Dakota.
August 14, 1979	Plant visit to American Crystal Sugar Company in Moorehead, Minnesota.
August 28, 1979	Plant visit to Goodyear Tires in Akron, Ohio.
August 28, 1979	Plant visit to Ohio Rubber Company in Willoughby, Ohio.
October 16, 1979	Plant visit to General Motors in St. Louis, Missouri.

October - November, 1979	Emission source testing at Mead Paperboard in Stevenson, Alabama.
November, 1979 - January, 1980	Continuous SO_2 Monitoring at Rickenbacker Air Force Base in Columbus, Ohio.
January - March 1980	Continuous SO_2 Monitoring at General Motors plant in Parma, Ohio.
January 1980 - March 1980	Continuous SO_2 Monitoring at General Motors in St. Louis, Missouri.
February 8, 1980	Plant visit to Tri-Valley Growers in Modesto, California.
February 8, 1980	Plant visit to California Canners and Growers in San Jose, California.
March 25, 1980	Plant visit to Brown-Forman Spirits in Louisville, Kentucky.
March 26, 1980	Plant visit to Jack Daniel Distillery in Lynchburg, Tennessee.
April 18, 1980	Plant visit to Great Lakes Steel in Ecorse, Michigan.
April 18, 1980	Plant visit to Republic Steel in Chicago, Illinois.
July 1, 1980	Plant visit to General Motors Corporation in Columbus, Ohio.
August 19, 1980	Plant visit to Celanese Fibers Amcell plant in Cumberland, Maryland.
August 20, 1980	Visit to Georgetown University fluidized bed combustion steam generator in Washington, D. C.
August 29, - September 24, 1980	Continuous SO_2 Monitoring at Celanese Fibers in Cumberland, Maryland.
November 10-17, 1980	Emission testing for particulate matter at General Motors in Parma, Ohio.
December 15-17, 1980	Emission source testing for particulate matter at DuPont and Company Washington Works in Parkersburg, West Virginia.

June 10, 1981	Plant visit to DuPont DeNemours Company in Martinsville, Virginia.
June 30, 1981	Plant visit to General Motors Chevrolet Plant in Parma, Ohio.
July 16, 1981	Plant visit to Tennessee Eastman Company in Kingsport, Tennessee.
August 1-4, 1981	Emission source testing at Caterpillar Tractor in Peoria, Illinois.
September 29 - October 2, 1981	Emission source testing at Boston Edison Company in Everett, Massachusetts.
December 1, 1981	Particulate emission test at Caterpillar Tractor Company in Peoria, Illinois.
March 2, 1982	Particulate emission source testing at General Motors plant, Hamilton, Ohio.

II. Meetings and Briefings

April 17, 1978	Meeting of project team members with Department of Energy (DOE) representatives.
April 18, 1978	Meeting of project team members with American Boiler Manufacturers Association (ABMA).
June 2, 1978	Meeting of project team members with DuPont representatives.
July 19, 1978	Meeting of project team members with ABMA.
December 6, 1978	EPA Working Group meeting.
December 8, 1978	EPA Steering Committee meeting.
January 10-11, 1979	NAPCTAC meeting on status of NSPS for industrial boilers.
February 15, 1979	Meeting of project team with ABMA, Industrial Gas Cleaning Institute, Department of Energy, and Council of Industrial Boiler Owners (CIBO).
February 28, 1979	Meeting of project team members with DOE representatives.

March 27, 1979	Meeting of project team with CIBO.
March 29, 1979	Presentation to National Association of Manufacturers in Washington, D.C.
June 11, 1979	Meeting of project team members with DOE to discuss energy scenarios that will be used in industrial boiler NSPS development.
June 19, 1979	Meeting of project team members with representatives of Combustion Engineering.
July 12, 1979	Meeting of project team members with CIBO representatives.
July, 1979	Meeting of contractor with United States Sugar Beet Association representative.
August 3, 1979	Meeting of contractor with National Food Processors Association representative.
October 4, 1979	Meeting of project team with General Motors representatives.
October 16, 1979	Meeting of project team with several industrial representatives.
October 17, 1979	Meeting of project team members with CIBO representatives.
October 26, 1979	Meeting of project team members with ABMA.
October 29, 1979	Meeting of project team with Rickenbacker Air Force Base representatives.
January 24, 1980	Meeting of project team members with National Food Processors Association representative.
February 11, 1980	Change of contractors from Acurex to Radian.
February 28, 1980	Team meeting to review project status.
March 18, 1980	Team meeting to discuss IFCAM results for Round 4 and set input conditions for Round 5.
July 9-10, 1980	NAPCTAC meeting.
September 24, 1980	Meeting of project team members and industry representatives on coal-limestone pellet status.

September, 1980	IFCAM working group meetings.
October, 1980	Project schedule revised to incorporate a second NAPCTAC meeting and two steering committee meetings.
November 6, 1980	Team meeting to discuss EPA's Office of Research and Development position on the IB NSPS.
November, 1980	Briefing held for Steering Committee.
November 15, 1980	Steering Committee meeting.
December 8, 1980	Meeting of project team members with ABMA representative.
March 12, 1981	Meeting of project team members with Charles Schmidt to discuss industrial boilers and emission controls.
March, 1981	Team meeting to outline remaining work on statistical analyses reports.
June, 1981	Team meeting to discuss preamble and regulation.
July 15, 1981	Team meeting to review adipic acid addition to FGD data, SO_2 report, fuel nitrogen/NO_x emission study, and respirable PM cost effectiveness.
February 9, 1982	Meeting with representatives of ABMA, CIBO, and Chemical Manufacturer's Association.
March 2, 1982	Meeting with representatives of ABMA to discuss NO_x control techniques for stoker boilers.
March 10, 1982	Meeting with representatives of ABMA to discuss NO_x control techniques for stoker boilers.

APPENDIX B

INDEX TO ENVIRONMENTAL CONSIDERATIONS

This appendix consists of a reference system which is cross indexed with the October 21, 1974, Federal Register (30 FR 37419) containing EPA guidelines for the preparation of Environmental Impact Statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the Federal Register guidelines.

There are, however, other documents and docket entries which also contain data and information, of both a policy and a technical nature, used in developing the proposed standards. This Appendix specifies only the portions of this document that are relevant to the indexed items.

TABLE B-1. INDEX TO ENVIRONMENTAL CONSIDERATIONS

Agency Guideline for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document
(1) Background and summary of regulatory alternatives	
Regulatory alternatives	The regulatory alternatives are summarized in Chapter 6.
Statutory basis for proposing standards	The statutory basis for the proposed standards is summarized in Chapter 2, Section 2.1.
Source category and affected industries	A discussion of the industrial boiler source category is presented in Chapter 3. Details of the "business/economic" nature of the industries affected are presented in Chapter 9.
Emission control technologies	A discussion of emission control technologies is presented in Chapter 4.

TABLE B-1. (CONTINUED)

Agency Guideline for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Locations Within the Background Information Document
(2) Environmental, Energy, and Economic Impacts of Regulatory Alternatives	
Regulatory alternatives	Various regulatory alternatives are discussed in Chapter 6.
Environmental impacts (Individual boilers)	The environmental impacts of various regulatory alternatives are presented in Chapter 7, Sections 7.1, 7.2 and 7.3.
Energy impacts (Individual boilers)	The energy impacts of various regulatory alternatives are discussed in Chapter 7, Section 7.4
Cost impacts (Individual boilers)	Cost impacts of various regulatory alternatives are discussed in Chapter 8.
Economic impacts (Individual boilers)	The economic impacts of various regulatory alternatives are presented in Chapter 9.
National and regional environmental, energy and cost impacts	The national and regional impacts of regulatory alternatives are presented in Chapter 9.

TABLE B-1. (CONTINUED)

Agency Guideline for Preparing Regulatory Action Environmental Impact Statements (39 FR 37419)	Location Within the Background Information Document
(3) Environmental impact of the regulatory alternatives	
Air pollution (Individual boilers)	The impact of the proposed standards on air pollution is presented in Chapter 7, Section 7.1.
Water pollution (Individual boilers)	The impact of the proposed standards on water pollution is presented in Chapter 7, Section 7.2.
Solid waste disposal (Individual boilers)	The impact of the proposed standards on solid waste disposal is presented in Chapter 7, Section 7.3.

APPENDIX C

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  C.1.1 Particulate Emission Data for Electrostatic Precipitators C-5
  C.1.2 Particulate Emission Data for Fabric Filters. C-28
  C.1.3 Particulate Emission Data for Mechanical Collectors . . C-51
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C.3 SO_2 EMISSION REDUCTION DATA. C-160

C.4 NO_x EMISSION REDUCTION DATA. C-194

C.5 REFERENCES C-262

APPENDIX C

Available emission data illustrating the performance levels achievable by various control systems evaluated in this study are presented in this appendix. The data are analyzed and discussed in Chapter 4. The data base is organized as follows:

Section C.1 - Particulate Emission Data
    C.1.1 - For Electrostatic Precipitators
    C.1.2 - For Fabric Filters
    C.1.3 - For Mechanical Collectors
    C.1.4 - For Dual Mechanical Collectors
    C.1.5 - For Wet Scrubbers
    C.1.6 - For Side-Stream Separators
Section C.2 - Visible Emission Data
Section C.3 - SO_2 Emission Data
Section C.4 - NO_x Emission Data
Section C.5 - References

For each data set presented in this Appendix, a brief description of the test site is provided which includes data such as (when available):

- Boiler type and rated capacity
- Load factor during test
- Type of emission control system
- Important emission control system design specifications (where known)
- Important emission control operating parameters (during test)
- Control system outlet emission level
- Test method used

All particulate and visible emission test sites are given a letter designation (example, Plant A). All SO_2 emission locations are given a roman numeral designation (example, Location I). Roman numerical designations are also given to all NO_x emission test locations.

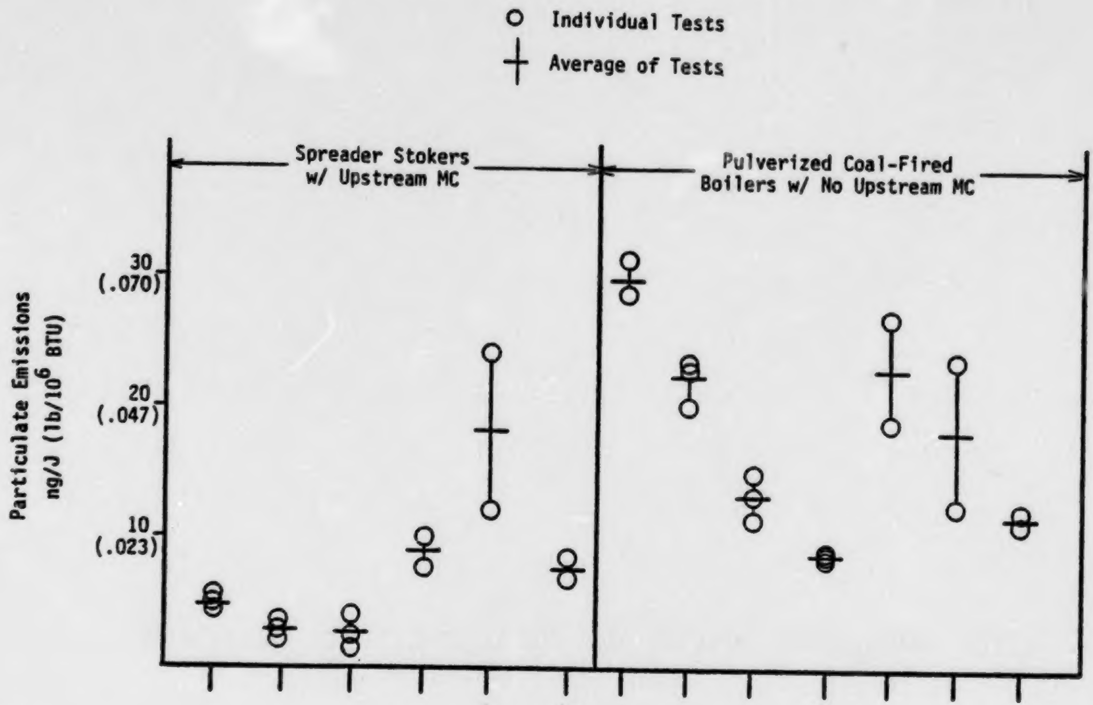
C.1 PARTICULATE EMISSION DATA

A majority of the particulate emission data presented here is from tests conducted by industrial boiler owners/operators. Other tests were conducted by the EPA. Each site was given a letter designation upon receipt of test data.

Data presented in Section C.1 are organized into subsections, as indicated on page C-1 of Appendix C. Each subsection presents the emission data for one type of control device. At the beginning of each subsection the emission test data are presented in graphical form. The first figure in each subsection is referred to as "support data". Support data is emission test data considered to be representative of the PM emission levels achievable with well designed, operated, and maintained control devices. This support data is presented and discussed in Chapter 4. If a second figure is shown in the subsection, it will contain all of the test data presented in that subsection including the data that, for various reasons, cannot be classified as support data. Such factors as lack of information on critical control device operating parameters or abnormal conditions during testing prevented some data from being classified as support data. Documentation of such factors is included in the description of each site. Site descriptions also include boiler type, manufacturer, and rated capacity, type of particulate control equipment, available design and/or operating parameters, and particulate matter test method. Most tests were conducted in accordance with EPA Method 5, but in some cases a high sample box temperature was used to avoid SO_3 condensation. (see Appendix D). These cases are identified in the site descriptions. Since most of the tests were conducted by different individuals, the same information is not available for each site or test. Opacity data was available for a small number of sites. Average opacity and test methods are stated.

Following each site description is an emission test summary sheet which includes the data and time of the test, isokinetic sampling ratios, and boiler load during testing. Stack gas data includes: velocity, flow, temperature, pressure and percent moisture. Fuel analyses are included when available and are for samples as received from suppliers unless stated otherwise.

C.1.1 PARTICULATE EMISSION DATA FOR ELECTROSTATIC PRECIPITATORS



Plant	K	K	K	P	N[b]	N[b]	Z	Z	Z	Z	W	W	W
Boiler Number	9	7	8	-	-	-	26	27	25	29	RC	BB	PG
Design Capacity (10^3 lb steam/hr)	125	75	100	200	300	300	430	430	430	430	380	300	300
Operating Capacity (% of Design)	99-102	103-106	93-98	87-89	76	52-59	95-98	96-97	99-100	99-100	72-85	86	91
SCA ($ft^2/10^3$ acfm)													
Design	128	132	152	349	344	344	90	96	98	98	300	369	325
Operating	128	128	160	397	542	634	90	96	98	98	348	348	364
Fuel Type[c]	B	B	B	B	SB	SB	B	B	B	B	-	-	-
Fuel Sulfur (Wt %)	.57	-	~1	.73	.54	.63	~1	~1	~1	~1	-	-	-
Fuel Ash (Wt %)	11.4	12.0	11.2	6.6	8.3	5.4	~12	~12	~12	~12	-	-	-
Fly Ash Reinjection	No	No	No	Yes	Yes	Yes	No	No	No	No	No	No	No

Figure C.1.1-1. Electrostatic precipitator emission data.[a]

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[a] All tests ordered from left to right by increasing SCA

[b] All tests done on a hot side ESP

[c] B-Bituminous coal, SB-Sub Bituminous coal

Plant K

Three spreader stoker boilers were tested at Plant K. The rated capacities of boilers 7, 8 and 9 are 92, 120 and 156 million Btu per hour (thermal output), respectively. Each is controlled by a mechanical collector placed in series with an electrostatic precipitator. The design SCA for ESP's on boilers 7, 8, and 9 are 132, 152 and 128 $ft^2/10^3$ acfm, respectively. The stack test reports were conducted for the West Virginia Pollution Control Commission under Regulation II and in accordance with EPA Method 5. Boiler Nos. 7 and 9 were operating above 100% capacity during testing while boiler No. 8 averaged 95% of capacity.[1] These operating capacities were calculated by using the orsat analysis results and the "F" factor method as outlined in AP-42.

PLANT K

Boiler # 7

TEST SUMMARY SHEETS (Particulates Only)[1]

Test Number	One	Two	Three	Average
General Data				
Date	12/9/76	12/9/76	12/9/76	
Time	0954	1350	0851	
Isokinetic Ratio (%)	99.4	99.8	98.1	99.1
Boiler Load (% of design)	103	105	106	105
Operating SCA (ft^2/10^3 acfm)				128
Gas Data				
Velocity (mps)				14.63
Velocity (fps)				48
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				285.6
Temperature (°F)				546
Pressure (inches W.C.)				
Moisture (%)	4.76	4.79	4.95	4.83
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	3.01	3.44	2.15	2.87
lb/10^6 Btu	0.007	0.008	0.005	0.007
Fuel Analysis				
Heating Value (kj/kg)	29239	28500	29252	28997
Heating Value (Btu/lb)	12571	12253	12576	12467
% Ash	11.5	12.38	12.07	11.98
% Sulfur				
Average Opacity (%)				

PLANT K

Boiler # 8

TEST SUMMARY SHEETS (Particulates Only)[1]

Test Number	One	Two	Three	Average
General Data				
Date	12/7/76	12/7	12/7	
Time	1155	0917	1335	
Isokinetic Ratio (%)	100.03	101.55	102.21	101.26
Boiler Load (% of design)	94	93	98	95
Operating SCA ($ft^2/10^3$ acfm)				160
Gas Data				
Velocity (mps)				8.84
Velocity (fps)				29
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				1.71
Temperature (°F)				340
Pressure (inches W.C.)				
Moisture (%)	5.57	5.15	5.41	5.38
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	3.87	1.72	2.15	2.58
$lb/10^6$ Btu	0.009	0.004	0.005	0.006
Fuel Analysis				
Heating Value (kj/kg)	29445	28805	29077	29110
Heating Value (Btu/lb)	12659	12384	12501	12515
% Ash	9.98	12.25	11.38	11.20
% Sulfur				~1
Average Opacity (%)				

PLANT K

Boiler # 9

TEST SUMMARY SHEETS (Particulates Only)[1]

Test Number	One	Two	Three	Average
General Data				
Date	7/24/75	7/24	7/24	
Time	8:21	13:00	18:10	
Isokinetic Ratio (%)	99.8	98.1	97.7	98.5
Boiler Load (% of design)	102	101	99	101
Operating SCA ($ft^2/10^3$ acfm)				128
Gas Data				
Velocity (mps)				10.36
Velocity (fps)				34
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				187.8
Temperature (°F)				370
Pressure (inches W.C.)				
Moisture (%)	8.23	8.45	8.58	8.42
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	5.59	5.16	4.3	5.02
$lb/10^6$ Btu	0.013	0.012	0.010	0.012
Fuel Analysis				
Heating Value (kj/kg)	26816	26079	26507	26463
Heating Value (Btu/lb)	11529	11212	11396	11377
% Ash	11.29	11.51	11.41	11.4
% Sulfur	0.60	0.57	0.55	0.57
Average Opacity (%)				

Plant N

The ABMA, DOE & EPA conducted tests at Plant N to determine boiler emissions and efficiency to help in the manufacture of more economical and environmentally satisfactory boilers and control equipment.

Plant N has two identical spreader stokers, each with a capacity of 300,000 pounds of steam per hour. Only one unit was tested. It is equipped with a mechanical collector and hot side electrostatic precipitator in series.* In addition, fly ash from the mechanical collector hopper is reinjected into the boiler.[2]

All tests were conducted in accordance with EPA Method 5. Nine tests were conducted at the mechanical collector outlet and four at the ESP outlet. The four ESP outlet tests are presented here. The two low load tests are averaged separately from the two high load tests.

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*The ESP design SCA is 344 $ft^2/10^3$ acfm. Average operating SCA for the low load tests was 634 $ft^2/10^3$ acfm, while the average operating SCA for the high load tests was 542 $ft^2/10^3$ acfm. Source: Kelly, M. E. (Radian Corporation). Telephone conversation with P. J. Langsjoen (KVB). ESP collector area. April 6, 1981.

PLANT N

Low Load Tests

TEST SUMMARY SHEETS (Particulates Only)[2]

Test Number	One	Two	Three	Average
General Data				
Date	8/30	8/31		
Time				
Isokinetic Ratio (%)	102	102		102
Boiler Load (% of design)	59	52		56
Operating SCA ($ft^2/10^3$ acfm)	605	662		634
Gas Data				
Velocity (mps)	20.46	18.93		19.70
Velocity (fps)	67.13	62.12		64.63
Flow (dnm^3/min)	1753.6	1554.8		1654.2
Flow (dscfm)	61920	54900		58410
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)	7.68	7.45		7.57
Particulate Emissions				
g/dnm^3	0.0174	0.0206		0.019
Gr/dscf	0.0076	0.0090		0.0083
ng/J	7.14	8.34		7.74
lb/10^6 Btu	0.0166	0.0194		0.018
Fuel Analysis				
Heating Value (kj/kg)	23188	24074		23631
Heating Value (Btu/lb)	9969	10350		10159
% Ash	6.79	3.94		5.37
% Sulfur	0.62	0.63		0.63
Average Opacity (%)	2.5	1.0		1.75

PLANT N
High Load Tests
TEST SUMMARY SHEETS (Particulates Only)[2]

Test Number	One	Two	Three	Average
General Data				
Date	10/29	10/30		
Time				
Isokinetic Ratio (%)	106	105		105.5
Boiler Load (% of design)	76	76		76
Operating SCA (ft^2/10^3 acfm)	571	512		542
Gas Data				
Velocity (mps)	24.07	27.23		25.65
Velocity (fps)		89.32		84.15
Flow (dnm^3/min)	78.97	2073.0		1966.8
Flow (dscfm)	1860.6	73200		69450
Temperature (°C)	65700			
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)	7.59	7.55		7.57
Particulate Emissions				
g/dnm^3	0.0648	0.0334		0.0341
Gr/dscf	0.0283	0.0146		0.0149
ng/J	24.77	12.73		18.80
lb/10^6 Btu	0.0576	0.0296		0.0436
Fuel Analysis				
Heating Value (kj/kg)	24502	24849		24676
Heating Value (Btu/lb)	10534	10683		10609
% Ash	8.79	7.81		8.3
% Sulfur	0.73	0.35		0.54
Average Opacity (%)				

Plant P

Plant P contains a Riley spreader stoker boiler with a rated capacity of 200,000 pounds of steam per hour. It is equipped with a mechanical dust collector and an electrostatic precipitator in series. Fly ash from the boiler and mechanical collector hoppers is reinjected into the boiler. The ESP has a design specific collection area of 349 $ft^2/10^3$ acfm. Two particulate emission tests were conducted at the ESP outlet. Test No. 1 was conducted at 87% of design capacity and at low O_2 conditions. Normal O_2 conditions existed during test No. 2 which was conducted at 89% of design capacity. Both tests were done according to EPA Method 5.[3]

PLANT P

TEST SUMMARY SHEETS (Particulates Only)[3]

Test Number	One	Two	Three	Average
General Data				
Date	2/16/78	2/7/78		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	87	89		88
Operating SCA ($ft^2/10^3$ acfm)	401	387		397
Excess Air (%)	25*	47		36
Gas Data				
Velocity (mps)	16.0	20.33		18.17
Velocity (fps)	52.48	66.71		59.6
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.028	0.018		0.023
Gr/dscf	0.012	0.008		0.01
ng/J	9.89	7.74		9.03
$lb/10^6$ Btu	0.023	0.018		0.021
Fuel Analysis				
Heating Value (kj/kg)	30659	30240		30450
Heating Value (Btu/lb)	13180	13001		13091
% Ash	6.47	6.69		6.58
% Sulfur	0.71	0.75		0.73
Average Opacity (%)				

* Low excess air test

Plant W

Three pulverized coal boilers (BB, PG & RC) were tested at Plant W. Boilers BB (400×10^6 Btu/hr heat output capacity) and PG (400×10^6 Btu/hr heat output capacity) are equipped with separate electrostatic precipitators. Exhaust gases are vented from the two ESP's to a common stack. Boiler RC (540×10^6 Btu/hr heat output capacity) is equipped with a separate ESP and stack. Outlet emissions for all boilers were measured at the ESP outlet. The design SCA's are 300, 369 and 325 $ft^2/10^3$ acfm for boilers RC, BB and PG, respectively.*

Two tests were conducted on each boiler. Boiler load during testing averaged 86 percent of capacity at unit BB, 91 percent of capacity at unit PG and about 80 percent of capacity at unit RC.[4,5]

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*Kelly, M. E. (Radian Corporation). Telephone conversation with M. L. Ransmeier (Champion Papers). ESP plate areas and design flow rates for boilers PG, RC, and BB. April 7, 1981.

PLANT W

Boiler RC

TEST SUMMARY SHEETS (Particulates Only)[4,5]

Test Number	One	Two	Three	Average
General Data				
Date	9/26/79	9/26/79		
Time	10:15-11:30	11:50-1:00		
Isokinetic Ratio (%)	102.79	103.57		103.15
Boiler Load (% of design)	72	85		79
Gas Data				
Velocity (mps)	15.59			
Velocity (fps)	51.14			
Flow (dnm^3/min)	2570.0	2763.0		2666.5
Flow (dscfm)	90745	97.565		94155
Temperature (°C)	190	204.4		197.8
Temperature (°F)	374	400		388
Pressure (inches W.C.)				
Moisture (%)	9.35	10.03		9.69
Oxygen	8.0	7.5		7.7
Particulate Emissions				
g/dnm^3	0.0723	0.0551		0.0637
Gr/dscf	0.0316	0.0241		0.0279
ng/J	26.96	18.71		22.79
lb/10^6 Btu	0.0627	0.0435		0.053
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)				

PLANT W

Boiler BB

TEST SUMMARY SHEETS (Particulates Only)[4,5]

Test Number	One	Two	Three	Average
General Data				
Date	10/8/79	10/8/79		
Time	4:30-10:45	10:55-12:05		
Isokinetic Ratio (%)	104.39	100.99		102.69
Boiler Load (% of design)	86	86		86
Gas Data				
Velocity (mps)	14.03	14.66		14.35
Velocity (fps)	46.03	48.10		47.07
Flow (dnm^3/min)	2175.7	2263.9		2219.8
Flow (dscfm)	76,824	79,941		78,383
Temperature (°C)	171.7	171		340.5
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)	7.2	7.7		7.5
Oxygen	7.5	8.0		7.7
Particulate Emissions				
g/dnm^3	0.0641	0.0303		0.0481
Gr/dscf	0.0280	0.0140		0.0210
ng/J	23.65	12.30		18.06
lb/10^6 Btu	0.0550	0.0286		0.042
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)				

PLANT W

Boiler PG

TEST SUMMARY SHEETS (Particulates Only)[4,5]

Test Number	One	Two	Three	Average
General Data				
Date	10/1/79	10/1/79		
Time	8:45-9:55	10:10-11:20		
Isokinetic Ratio (%)	105.02	104.70		104.86
Boiler Load (% of design)	90.8	90.8		90.8
Gas Data				
Velocity (mps)	13.56	13.79		13.68
Velocity (fps)	44.5	45.24		44.87
Flow (dnm^3/min)	2050.0	2191.9		2120.6
Flow (dscfm)	72,386	77,370		74878
Temperature (°C)	161.7	148.9		155.6
Temperature (°F)	323	300		312
Pressure (inches W.C.)				
Moisture (%)	11	9.3		10.2
Oxygen (%)	7.0	6.0		6.5
Particulate Emissions				
g/dnm^3	0.0368	0.0314		0.0341
Gr/dscf	0.0161	0.0137		0.0149
ng/J	12.04	10.96		11.61
lb/10^6 Btu	0.0280	0.0255		0.027
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)				

Plant Z

Four pulverized coal boilers (Nos. 25, 26, 27 and 29) with an approximate capacity of 430,000 pounds of steam per hour each were tested at Plant Z. Boiler Nos. 25, 26, 27 and 29 are all equipped with separate mechanical dust collectors and Buell electrostatic precipitators. Each ESP has a total plate area of 19,335 ft^2. The mechanical collectors were not in use during testing. The Buell ESPs were found to be more efficient when the mechanical collectors were not operating. All tests were done in accordance with EPA Method 5. Three test runs were conducted at each of the five boilers. During testing, the ESPs provided an average specific collection area of 98, 90, 96 and 98 $ft^2/10^3$ acfm for boilers 25, 26, 27 and 29, respectively. The boilers were operating at or near capacity. Therefore, the operating SCA's are equal to the design SCA's.

PLANT Z

Boiler 25

TEST SUMMARY SHEETS (Particulates Only)[6]

Test Number	One	Two	Three	Average
General Data				
Date	12/5/78	12/5/78	12/5/78	
Time	8:23-9:32	10:03-11:15	11:35-12:44	
Isokinetic Ratio (%)	100	99.6	98.7	99.2
Boiler Load (% of design)				
Operating SCA ($ft^2/10^3$ acfm)				98
Gas Data				
Velocity (mps)	15.61	15.7	16.0	15.76
Velocity (fps)	51.2	51.5	52.4	51.7
Flow (dnm^3/min)	3596.6	3540	3596.6	3568.3
Flow (dscfm)	127,000	125,000	127,000	126,000
Temperature (°C)	131	138	141	137
Temperature (°F)	268	281	285	278
Pressure (inches W.C.)				
Moisture (%)	2.91	6.71	6.74	6.80
Particulate Emissions				
g/dnm^3	0.030	0.039	0.034	0.034
Gr/dscf	0.013	0.017	0.015	0.015
ng/J	11.35	14.84	13.07	13.07
$lb/10^6$ Btu	0.0264	0.0345	0.0304	0.0304
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				12
% Sulfur				~1
Average Opacity (%)				

PLANT Z

Boiler #26

TEST SUMMARY SHEETS (Particulates Only)[6]

Test Number	One	Two	Three	Average
General Data				
Date	12/2	12/2	12/2	1978
Time	8:20-9:30	10:05	1143	
Isokinetic Ratio (%)	95.7	94.9	97.7	96.1
Boiler Load (% of design)				
Operating SCA ($ft^2/10^3$ acfm)				90
Gas Data				
Velocity (mps)	16.76	17.13	17.47	17.16
Velocity (fps)	55.0	56.2	57.3	56.3
Flow (dnm^3/min)	3766.6	3851.5	3851.5	3823.2
Flow (dscfm)	133000	136000	136000	135000
Temperature (°C)	133	138	142	137
Temperature (°F)	271	280	287	279
Pressure (inches W.C.)				
Moisture (%)	7.85	6.86	7.62	7.44
Particulate Emissions				
g/dnm^3	0.076	0.076	0.082	0.078
Gr/dscf	0.033	0.033	0.036	0.034
ng/J	28.77	28.77	31.39	29.67
$lb/10^6$ Btu	0.0669	0.0669	0.0730	0.0690
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				12
% Sulfur				~1
Average Opacity (%)				

PLANT Z

Boiler #27

TEST SUMMARY SHEETS (Particulates Only)[6]

Test Number	One	Two	Three	Average
General Data				
Date	12/1	12/1	12/1	1978
Time	8:50	10:38	12:27	
Isokinetic Ratio (%)	96	97	96.7	96.6
Boiler Load (% of design)				
Operating SCA ($ft^2/10^3$ acfm)				96
Gas Data				
Velocity (mps)	16.31	16.19	15.94	16.12
Velocity (fps)	53.5	53.1	52.3	52.9
Flow (dnm^3/min)	3794.9	3766.6	3681.6	3738.2
Flow (dscfm)	134000	133000	130000	132000
Temperature (°C)	124	125	127	126
Temperature (°F)	256	257	260	258
Pressure (inches W.C.)				
Moisture (%)	7.62	7.76	7.85	7.74
Particulate Emissions				
g/dnm^3	0.060	0.048	0.062	0.057
Gr/dscf	0.026	0.021	0.027	0.025
ng/J	22.66	19.69	23.05	21.67
$lb/10^6$ Btu	0.0527	0.0458	0.036	0.0504
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				12
% Sulfur				~1
Average Opacity (%)				

PLANT Z

Boiler #29

TEST SUMMARY SHEETS (Particulates Only)[6]

Test Number	One	Two	Three	Average
General Data				
Date	11/30	11/30	11/30	1978
Time	11:37	1:40	3:25	
Isokinetic Ratio (%)	95.9	95.5	96.6	96.0
Boiler Load (% of design)				
Operating SCA ($ft^2/10^3$ acfm)				98
Gas Data				
Velocity (mps)	15.70	15.73	15.67	15.20
Velocity (fps)	51.5	51.6	51.4	51.5
Flow (dnm^3/min)	3596.6	3568.3	3568.3	3568.3
Flow (dscfm)	127000	126000	126000	126000
Temperature (°C)	133	133	133	133
Temperature (°F)	271	271	271	271
Pressure (inches W.C.)				
Moisture (%)	7.48	7.91	7.51	7.63
Particulate Emissions				
g/dnm^3	0.025	0.025	0.023	0.025
Gr/dscf	0.011	0.011	0.010	0.011
ng/J	8.99	8.86	8.17	8.9
$lb/10^6$ Btu	0.0290	0.0206	0.0190	0.0207
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				12
% Sulfur				~1
Average Opacity (%)				

Plant HHH

This 585 megawatt boiler/generator system supplies electrical power to a central grid system. The boiler fires a high sulfur, high vanadium residual oil and is typically base loaded at or near 560 megawatts. Designed by combustion engineering the boiler is a controlled circulation, tangentially fired (cyclone type) utility boiler. The design excess air value is 3 percent. However, during the testing the excess air valves ranged between 6.0 and 7.5 percent. This was reportedly normal boiler operation. In general the boiler maintained steady state normal operation throughout the testing period. Soot was blown continuously during the emission testing.

Flue gas from two preheaters are directed to the Buell modular electrostatic precipitator which is a split flow unit. After leaving the precipitator, flue gases from both sides are combined and exhausted to a common stack.[7]

PLANT HHH

Boiler No. 7

Method 5 - Low Temperature

TEST SUMMARY SHEETS (Particulates Only)[7]

Test Number	One	Two	Three	Average
General Data				
Date	9/30/81	10/1/81	10/2/81	
Time	10:17-4:50	10:40-2:30	9:57-12:45	
Isokinetic Ratio (%)	98.0	100.5	95.6	98.0
Boiler Load (% of design)	101.4	101.6	100.7	101.2
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm³/min)	29900	29700	30800	30133
Flow (dscfm)	105800	104800	108600	106400
Temperature (°C)	167	183	183	178
Temperature (°F)	333	361	361	352
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm³	0.086	0.126	0.090	0.101
Gr/dscf	0.038	0.055	0.039	0.044
ng/J	28.1	44.0	30.2	34.1
lb/10^6 Btu	0.065	0.102	0.070	0.079
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)				

PLANT HHH

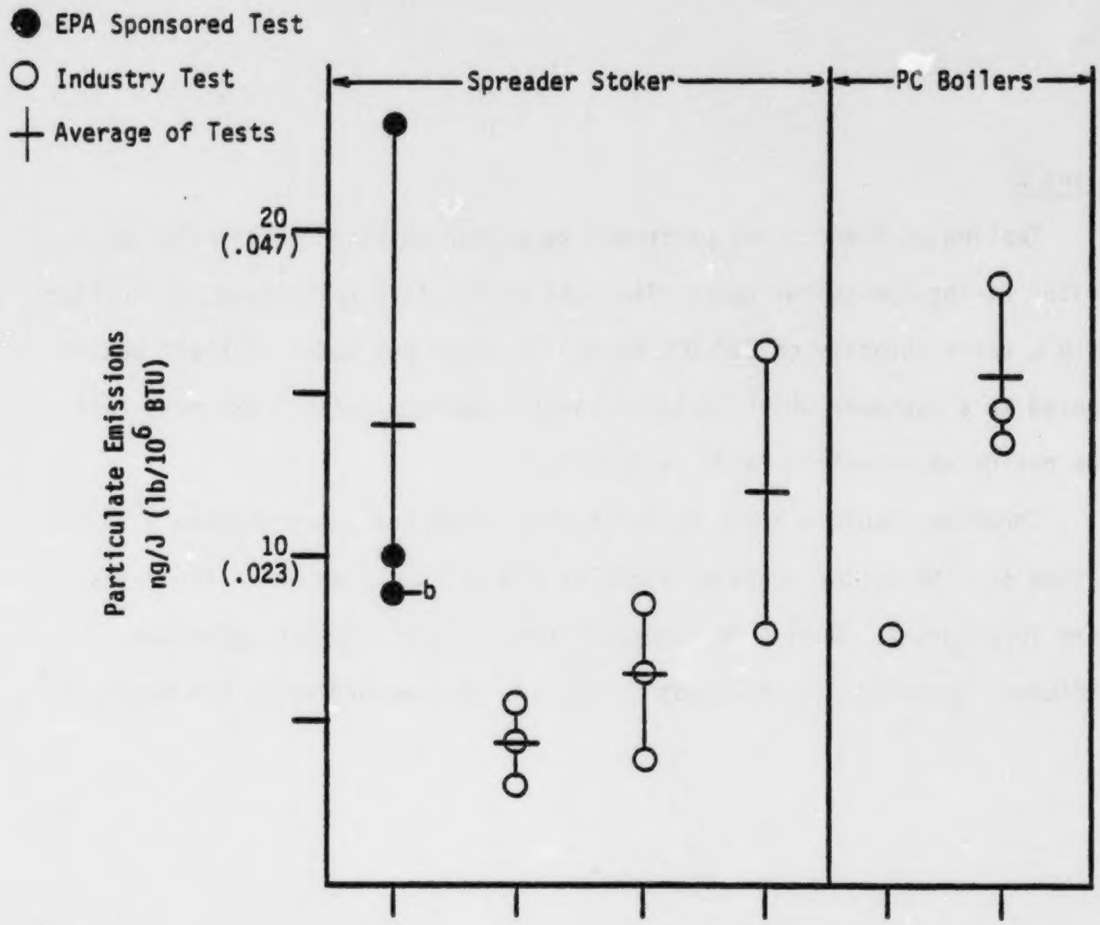
Boiler No. 7

Method 5 - High Temperature

TEST SUMMARY SHEETS (Particulates Only)[7]

Test Number	One	Two	Three	Average
General Data				
Date	9/30/81	10/1/81	10/2/81	
Time	10:17-4:50	10:40-2:30	9:57-12:45	
Isokinetic Ratio (%)	98.6	101.1	100.8	100.2
Boiler Load (% of design)	101.4	101.6	100.7	101.2
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)	29800	29400	29100	29433
Flow (dscfm)	105200	103800	102800	103933
Temperature (°C)	167	183	183	178
Temperature (°F)	333	361	361	352
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.054	0.060	0.057	0.057
Gr/dscf	0.024	0.026	0.025	0.025
ng/J	17.7	21.0	19.4	19.4
lb/10^6 Btu	0.041	0.049	0.045	0.045
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)				

C.1.2. PARTICULATE EMISSION DATA FOR FABRIC FILTERS



Plant	J2	EE	EE	EE	KK	C
Boiler Number	4	4	2	5	-	-
Design Capacity						
(10^3 lb steam/hr)	55	100	50	150	260	250
(10^6 Btu/hr)	-	125	64	181	-	-
Operating Capacity (% of Design)	84-96	77-78	98-100	96	83	100
Air/Cloth acfm/ft^2						
Design	2.5	3.7	3.4	3.7	1.9	2.3
Operating	2.3	2.9	3.4	3.6	1.7	2.2
Fuel Sulfur (Wt %)	0.83	2.6	2.7	2.95	0.73	0.52
Fuel Ash (Wt %)	6.9	7.0	7.0	6.5	15.0	10.2

Figure C.1.2-1. Fabric filter emission data.[a]

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[a] All tests ordered from left to right by increasing air-to-cloth ratio

[b] This test includes a soot blowing cycle

Plant C

Testing at Plant C was performed to gather emission information on a boiler firing low-sulfur coal. The unit tested is a pulverized coal boiler with a rated capacity of 250,000 pounds of steam per hour. Exhaust gas is vented to a baghouse which contains eight compartments with 180 bags each. The design air-to-cloth ratio is 2.26 to 1.

Three particulate emission tests were conducted in accordance with EPA Method 5. The boiler operated normally and at full load while the tests were in progress. During test number three, a soot blowing cycle was included. Opacity, which averaged 2.5, was read according to EPA Method 9.[8]

PLANT C

TEST SUMMARY SHEETS (Particulates Only)[8]

Test Number	One	Two	Three*	Average
General Data				
Date	6/7/77	6/8/77	6/8/77	
Time				
Isokinetic Ratio (%)	100.1	100.7	101.3	100.7
Boiler Load (% of design)	100	100	100	100
Operating A/C (acfm/ft^2)	2.2	2.2	2.2	2.2
Gas Data				
Velocity (mps)	13.12	13.13	~12.5	12.99
Velocity (fps)	43.001	43.060	41.803	42.623
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)	179.4	179.4	179.4	179.4
Temperature (°F)	355.0	355.0	355	355
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.0442	0.0406	0.0657	0.0502
Gr/dscf	0.01931	0.01774	0.02871	0.02192
ng/J	14.45	13.59	18.41	15.48
lb/10^6 Btu	0.0336	0.0316	0.0428	0.0360
Fuel Analysis				
Heating Value (kj/kg)	25723	25055	26263	25681
Heating Value (Btu/lb)	11058	10771	11290	11040
% Ash	11.76	10.78	8.10	10.18
% Sulfur	.57	.54	.47	.52
Average Opacity (%)	2.5	2.5	2.5	2.5

*Soot blow cycle included.

Plant J2

Boiler nos. 3 and 4 at Plant J2 are Babcock and Wilcox spreader stokers, with a combined steam generating capacity of 55 x 10^3 lb/hr. Induced draft fan vents flue gas from the two boilers to a common baghouse (16,560 ft^2, four compartment Wheelabrator Frye baghouse), which has design air-to-cloth ratio of 3.4 acfm/ft^2 (three compartments in service) and 2.5 acfm/ft^2 (four compartments in service).

Three test runs were conducted on boiler no. 4 according to EPA Method 5 in July 1979. The boiler averaged 27,500 pounds of steam per hour, approximately 93% of capacity during the test run.[9]

Soot blowing was conducted during test three on boiler no. 4 for about seven minutes. Grain loading from that boiler was doubled without increasing the grain loading at the filter outlet. Soot is normally blown once per day for about 90 seconds per boiler.

PLANT J2

TEST SUMMARY SHEETS (Particulates Only)[9,10]

Test Number	One	Two	Three *	Average
General Data				
Date	4/16/80	4/17/80	4/17/80	
Time				
Isokinetic Ratio (%)	104.2	104.3	104.1	104.2
Boiler Load (% of design)				84-96
Operating A/C (acfm/ft^2)	2.2	2.3	2.3	2.3
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				750
Flow (dscfm)	25958	26672	26797	26476
Temperature (°C)	127.1	122.7	134.1	128.0
Temperature (°F)	260.8	252.9	273.3	262.3
Pressure (inches W.C.)				
Moisture (%)	4.2	5.0	4.1	4.6
Particulate Emissions				
g/dnm^3	0.018	0.030	0.016	0.021
Gr/dscf	0.00743	0.02039	0.00707	0.00116
ng/J	9.99	23.3	8.94	14.08
lb/10^6 Btu	.0230	0.0541	0.0208	0.0326
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash	5.87	4.58	10.91	6.88
% Sulfur	0.63	0.97	0.88	0.83
Average Opacity (%)	<1	<1	<1	<1

* Including a seven minute soot blowing cycle on boiler no. 4 during test three.

Plant EE

Four spreader stoker boilers were tested at Plant EE. Boilers 2, 4, 5 and 6 have rated capacities of 64, 125, 181 and 241 million Btu per hour, respectively, with steam capabilities of 50,000 100,000, 150,000, and 200,000 lb/hr respectively. Each is equipped with a single stage multicyclone mechanical collector followed by a baghouse. The baghouses on boilers 2, 4, 5 and 6 use pulse jet cleaning. The baghouse on boiler 2 is 12x12x40 feet with five compartments containing 490, 6.25 inch diameter by 9 feet, bags. The filter cloth area is 7,400 ft^2 providing an air-to-cloth ratio of 3.4 $acfm/ft^2$. There are two baghouses on boiler 4, each 12x12x30 feet total with six compartments containing 840 bags, 6.25 inch diameter by 9 feet. The total filter cloth area is 12,600 ft^2 providing an air-to-cloth ratio of 3.7 $acfm/ft^2$. Boiler 5 is equipped with two baghouses, each 12x12x40 feet with six compartments containing 1176 bags, 6.25 inch diameter by 9 feet. The total filter cloth area is 17,600 ft^2 providing an air-to-cloth ratio of 3.7 $acfm/ft^2$. Boiler 6 has two baghouses, each 12x12x50 feet. Six compartments containing 1512, 6.25 inch diameter by 9 feet, bags provide a total filter area of 22,700 ft^2. This provides an air-to-cloth ratio of 3.8 $acfm/ft^2$. The baghouses for boiler 2, 4, 5 and 6 are designed for airflows at 350°F of 25,000, 46,000, 65,000 and 86,000 acfm respectively. Exhaust gas from boilers 2 and 4 is vented to stack no. 1. Gas from boilers 5 and 6 is vented to stack no. 3.[11]

Three compliance tests were conducted at each boiler under Regulation II, (1974) for the State of West Virginia Air Pollution Control Commission.

Chemical analysis performed on the particulate captured during testing on boiler 6 revealed that close to 50 percent of the catch was sulfate. This sulfate would not have been present had the filter and probe been maintained at 275°F (above the acid dew point). Therefore, all test results for boiler 6 have been removed from the support data figures.

Prior to testing boiler number 5, the baghouse was inadvertantly "overcleaned", resulting in a higher than normal three day average emission rate. Emissions diminished over the three day test period with equilibrium reached in between tests 2 and 3. For this reason test 1 has been eliminated from the support data figures, and from calculation of the average values reported in the Test Summary Sheet.

The stack opacities were consistently less than 10 percent on the Lear-Seigler monitors mounted on the breeching at the entrance to the stacks.

PLANT EE

Boiler #2

TEST SUMMARY SHEETS (Particulates Only)[11]

Test Number	One	Two	Three	Average
General Data				
Date	3/16/76	3/16/76	3/16/76	
Time	1:00	10:00	9:15	
Isokinetic Ratio (%)	102.4	103.6	101.1	102.4
Boiler Load (% of design)	98.2	98.2	99.6	98.7
O_2 (% by volume, dry basis)	6.0	6.5	6.4	6.3
Operating A/C (acfm/ft^2)	3.46	3.46	3.41	3.44
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)	5.5	5.44	4.86	5.27
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	8.6	6.45	3.87	6.45
lb/10^6 Btu	0.020	0.015	0.009	0.015
Fuel Analysis				
Heating Value (kj/kg)	31294	31622	32136	31684
Heating Value (Btu/lb)	13454	13595	13816	13622
% Ash	7.44	6.79	6.47	6.90
% Sulfur	2.79	2.8	2.65	2.75
Average Opacity (%)	<10	<10	<10	<10

PLANT EE

Boiler #4

TEST SUMMARY SHEETS (Particulates Only)[11]

Test Number	One	Two	Three	Average
General Data				
Date	3/23/76	3/24/76	3/25/76	
Time	1605	1620	1015	
Isokinetic Ratio (%)	95.1	93.7	93	
Boiler Load (% of design)	76.8	77.6	77.3	77.2
O_2 (% volume, dry basis)	6.7	6.69	6.0	
Operating A/C (acfm/ft^2)	2.8	2.9	2.9	2.89
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)	5.1	5.3	5.9	5.4
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	5.59	4.3	3.01	4.3
lb/10^6 Btu	0.013	0.010	0.007	0.010
Fuel Analysis				
Heating Value (kj/kg)	31199	31490	31520	31403
Heating Value (Btu/lb)	13413	13538	13551	13501
% Ash	7.48	6.64	6.89	7.0
% Sulfur	2.43	2.65	2.83	2.6
Average Opacity (%)	<10	<10	<10	<10

PLANT EE

Boiler #5

TEST SUMMARY SHEETS (Particulates Only)[11]

Test Number	One *	Two	Three	Average
General Data				
Date	11/4/75	11/5/75	11/6/75	—
Time	1200	1140	1140	—
Isokinetic Ratio (%)	93.54	94.6	96.4	—
Boiler Load (% of design)	96.5	96	96.4	96.2
O_2 (% volume, dry basis)	5.58	5.32	5.41	5.37
Operating A/C (acfm/ft^2)	3.6	3.6	3.6	3.6
Gas Data				
Velocity (mps)	—	—	—	—
Velocity (fps)	—	—	—	—
Flow (dnm^3/min)	—	—	—	—
Flow (dscfm)	—	—	—	—
Temperature (°C)	—	—	—	—
Temperature (°F)	—	—	—	—
Pressure (inches W.C.)	—	—	—	—
Moisture (%)	6.21	6.31	6.85	6.58
Particulate Emissions				
g/dnm^3	—	—	—	—
Gr/dscf	—	—	—	—
ng/J	58.48	16.34	7.74	12.04
lb/10^6 Btu	0.136	0.038	0.018	0.028
Fuel Analysis				
Heating Value (kj/kg)	31729	32245	31948	32097
Heating Value (Btu/lb)	13641	13863	13735	13799
% Ash	6.98	6.46	6.44	6.45
% Sulfur	3.0	2.92	2.98	2.95
Average Opacity (%)	< 10	< 10	< 10	< 10

* This test not included in the support data figures. Prior to testing baghouse was "overcleaned' resulting in higher than normal emission rate.

PLANT EE

Boiler #6*

TEST SUMMARY SHEETS (Particulates Only)[11]

Test Number	One	Two	Three	Average
General Data				
Date	12/17/75	12/18/75	12/18/75	
Time	1712	1050	20:02	
Isokinetic Ratio (%)	103.3	104.41	103.11	103.6
Boiler Load (% of design)	98.3	98.9	98	98.4
O_2 (% volume, dry basis)	5.23	4.72	4.98	4.98
Operating A/C (acfm/ft	3.7	3.8	3.7	3.7
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)	5.98	6.47	5.89	6.11
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	30.53	7.74	18.92	18.92
$lb/10^6$ Btu	0.071	0.018	0.044	0.044
Fuel Analysis				
Heating Value (kj/kg)	30878	30899	31029	30936
Heating Value (Btu/lb)	13275	13284	13340	13300
% Ash	7.27	7.97	7.03	7.42
% Sulfur	2.81	2.88	2.88	2.86
Average Opacity (%)	<10	<10	<10	<10

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* This data is not included in support data figures. Proper probe temperature was not maintained during tests.

Plant JJ

Plant JJ contains a nine compartment baghouse which cleans the flue gas from three spreader stokers. These stokers have a combined capacity of 260,000 lb/hr of steam. All of the stokers utilize fly ash reinjection techniques. At maximum capacity the baghouse has an air-to-cloth ratio of 3.38 acfm/ft^2. These boilers primarily produce steam for space heating. In warm weather these boilers each produce as low as 30,000 lb/hr of steam. The boilers produce as much as 180,000 lb/hr in cold weather.

Three tests were run with the pulse-jet cleaning mode. Three additional tests were run with the reverse-air cleaning mode. Particulate emission tests were conducted in accordance with EPA Method 5 while opacity readings were taken according to EPA Method 9 . The tests were carried out in April and are therefore at relatively low loads (25-31% of design). Because very low load operation may not be representative of normal operation these tests are not included in support data figures.[12] The opacity data were used in the opacity section.

PLANT JJ*

TEST SUMMARY SHEETS (Particulates Only)[12]

Pulse Jet Cleaning Mode

Test Number	One	Two	Three	Average
General Data				
Date	4/4/77	4/5/77	4/5/77	
Time				
Isokinetic Ratio (%)	96.9	97.6	98.8	97.8
Boiler Load (% of design)	28	31	30	30
Operating A/C (acfm/ft^2)	1.0	1.1	1.0	1.0
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)	538	617	583	579
Flow (dscfm)	19,000	21,800	20,600	20,500
Temperature (°C)				
Temperature (°F)	318	333	337	329
Pressure (inches W.C.)				
Moisture (%)	5.7	5.3	5.8	5.6
Oxygen (%)	10.8	9.6	8.8	9.7
Particulate Emissions				
g/dnm^3	0.016	0.011	0.034	0.021
Gr/dscf	0.007	0.005	0.015	0.009
ng/J	8.6	5.6	15.5	9.9
lb/10^6 Btu	0.020	0.013	0.036	0.023
Fuel Analysis				
Heating Value (kj/kg)	27186	27319	26954	27153
Heating Value (Btu/lb)	11,688	11,745	11,588	11674
% Ash	10.65	10.65	11.36	10.68
% Sulfur	2.07	1.79	1.62	1.93
Average Opacity (%)		0		

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* Due to low load operation these tests are not included in the support data figures, but they are included in the opacity section.

PLANT JJ*

TEST SUMMARY SHEETS (Particulates Only)[12]

Reverse Air Cleaning Mode

Test Number	One	Two	Three	Average
General Data				
Date	4/6/77	4/7/77	4/7/77	
Time				
Isokinetic Ratio (%)	97.2	96.5	97.3	97.0
Boiler Load (% of design)	31	26	25	27
Operating A/C (acfm/ft^2)	1.1	1.0	1.0	1.0
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)	615	507	507	543
Flow (dscfm)	21,700	17,900	17,900	19,200
Temperature (°C)				
Temperature (°F)	332	325	315	324
Pressure (inches W.C.)				
Moisture (%)	5.1	5.7	5.1	5.3
Oxygen (%)	10.5	9.7	11.4	10.5
Particulate Emissions				
g/dnm^3	0.009	0.009	0.007	0.009
Gr/dscf	0.004	0.004	0.003	0.004
ng/J	4.7	4.3	3.9	4.3
lb/10^6 Btu	0.011	0.010	0.009	0.010
Fuel Analysis				
Heating Value (kj/kg)	28003	25500	27980	27161
Heating Value (Btu/lb)	12039	10963	12029	11677
% Ash	8.00	7.81	8.91	8.24
% Sulfur	1.86	1.64	1.53	1.68
Average Opacity (%)	<1	0	0	<1

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* Due to the low load operation, this data is not included in the support data figures.

Plant KK

Plant KK has two pulverized coal-fired boilers. Boiler 7, with a rated capacity of 260,000 lb/hr steam, was tested. Fly ash is removed by a ten-compartment baghouse. The baghouse is designed to handle a flue gas flow of 165,000 acfm between 270 and 500°F, with a pressure drop of 8 inches W.G. Each compartment of the baghouse contains 96, 11.5 inch diameter by 30 feet, bags, providing a total filter area of 86,708 ft^2. This provides a design air-to-cloth ratio of 1.9 $acfm/ft^2$.

Test runs were made both with normal excess air to the boiler and with low excess air to the boiler. All tests were conducted in accordance with EPA Method 5.[13] Boiler loads ranged from 67 - 83 percent of design with all tests but one conducted at loads above 75 percent of design. Tests at loads less than 75 percent were not included in the support data figures.

PLANT KK*

TEST SUMMARY SHEETS (Particulates Only)[13]

Low Excess Air Tests

Test Number	One	Two	Three	Average
General Data				
Date	6/7/79	6/8/79	6/12/79	7/11/79
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	65	64	63	64
Operating A/C (acfm/ft^2)	1.3	1.3	1.3	1.3
Gas Data				
Velocity (mps)	10.1	10.3	10.2	10.1
Velocity (fps)	33.3	33.8	33.5	33
Flow (dnm^3/min)				
Flow (dscfm)	69947	71646	74847	70983
Temperature (°C)	152	149	149	160
Temperature (°F)	305	300	300	320
Pressure (inches W.C.)				
Moisture (%)				
Oxygen (%)	7.4	7.0	7.1	7.8
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	12.8	8.4	7.8	7.5
lb/10^6 Btu	0.030	0.020	0.018	0.006
Fuel Analysis				
Heating Value (kj/kg)	10160	10160	10160	10910
Heating Value (Btu/lb)	14.95	14.95	14.95	7.36
% Ash	0.73	0.73	0.73	0.30
% Sulfur				
Average Opacity (%)	0	0	0	0

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* Due to low boiler loads all low excess air tests are not included in the support data figures, but they are used in the opacity section.

PLANT KK*

TEST SUMMARY SHEETS (Particulates Only)[13]

Low Excess Air Tests

Test Number	One	Two	Three	Average
General Data				
Date	7/11/79	7/12/79		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	71	65		65
Operating A/C (acfm/ft^2)	1.5	1.4		1.4
Gas Data				
Velocity (mps)	11.9	10.7		10.5
Velocity (fps)	39	35		34.6
Flow (dnm^3/min)				
Flow (dscfm)	82816	76229		74411
Temperature (°C)	160	160		155
Temperature (°F)	320	320		311
Pressure (inches W.C.)				
Moisture (%)				
Oxygen (%)	7.7	7.6		7.4
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	7.2	7.2		7.2
lb/10^6 Btu	0.007	0.008		0.008
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)	10910	10910		10535
% Ash	7.36	7.36		11.16
% Sulfur	0.30	0.30		0.52
Average Opacity (%)	0	0		0

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* Due to low boiler loads, all low excess air tests are not included in the support data figures, but they are used in the opacity section.

PLANT KK

TEST SUMMARY SHEETS (Particulates Only)[13]

Normal Excess Air Tests

Test Number	One	Two *	Three *	Average
General Data				
Date	6/14/79	7/10/79	7/10/79	
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	83	67	73	74
Operating A/C (acfm/ft^2)	1.7	1.5	1.5	1.6
Gas Data				
Velocity (mps)	13.9	11.9	11.4	12.4
Velocity (fps)	45.5	39.0	37.3	40.7
Flow (dnm^3/min)				
Flow (dscfm)	96029	84315	79550	86628
Temperature (°C)	155	161	169	161
Temperature (°F)	310	321	335	322
Pressure (inches W.C.)				
Moisture (%)				
Oxygen (%)	8.1	8.2	8.3	8.3
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	7.8	6.4	4.3	6.2
lb/10^6 Btu	0.018	0.015	0.010	0.014
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)	10160	10910	10910	10660
% Ash	14.95	7.36	7.36	9.89
% Sulfur	0.73	0.30	0.30	0.44
Average Opacity (%)	0	0	0	0

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* Due to low boiler loads these tests are not included in the support data figures, but they are used in the opacity section.

Plant K2

Plant K2 consists of a 100,000 lb/hr coal/limestone feed fluidized-bed boiler (FBB). The FBB is a two-bed, single-cell, top-suspended, balanced draft, natural circulation boiler capable of generating steam at 275 psig for delivery into the steam header for heating and cooling of 204,000 m^2 of building space. Saturated steam at 625 psig can also be produced for delivery into the header through a pressure regulation valve, with provisions for future cogeneration of electrical energy.

The design and operation of the FBB is based on classical fluidized-bed principles; i.e., use of low superficial velocity in the range of 1.2 to 24 m/sec (4 to 8 ft/sec), and primary recirculation of entrained solids to the combustion chamber. Coal is fed into each bed using separate conventional spreader stoker overbed feeders. Limestone is fed by gravity at a single point in each bed. Design parameters for the FBB include:

- Bed Dimensions	19'-4" x 11'-0 (2 segments)
- Coal Type	Bituminous
- Bed Temperature	1,594°F
- Fluidizing Velocity	8 ft/sec
- Ca/S Ratio	3
- Efficiency (Thermal)	83.51%
- Reinjection Flow	7,500 lb/hr

Particulate control is effected by passing flue gas through a multicyclone (primary control) and baghouse (final control). Fly ash from the multicyclone hopper is reinjected on a continuous basis. The test report for Plant K2 supplied no design data for the particulate control devices.

Two or three boiler/baghouse operating conditions may have increased particulate emission rates to higher than expected rates, as measured on

August 23. Factors which may have increased baghouse inlet loadings include inefficient multicyclone performance due to clogging and excessive bed elutriation induced by injection of overfire air near the top of bed A. Baghouse efficiency may have been lower than design (inlet concentrations were not measured using EPA reference method procedures) due to bag punctures and apparent blinding of the Teflon bags interspersed throughout several baghouse compartments.

Prior to measurements made on September 13, several damaged bags were replaced and baghouse performance improved.

PLANT K2

TEST SUMMARY SHEETS (Particulates Only)[53]

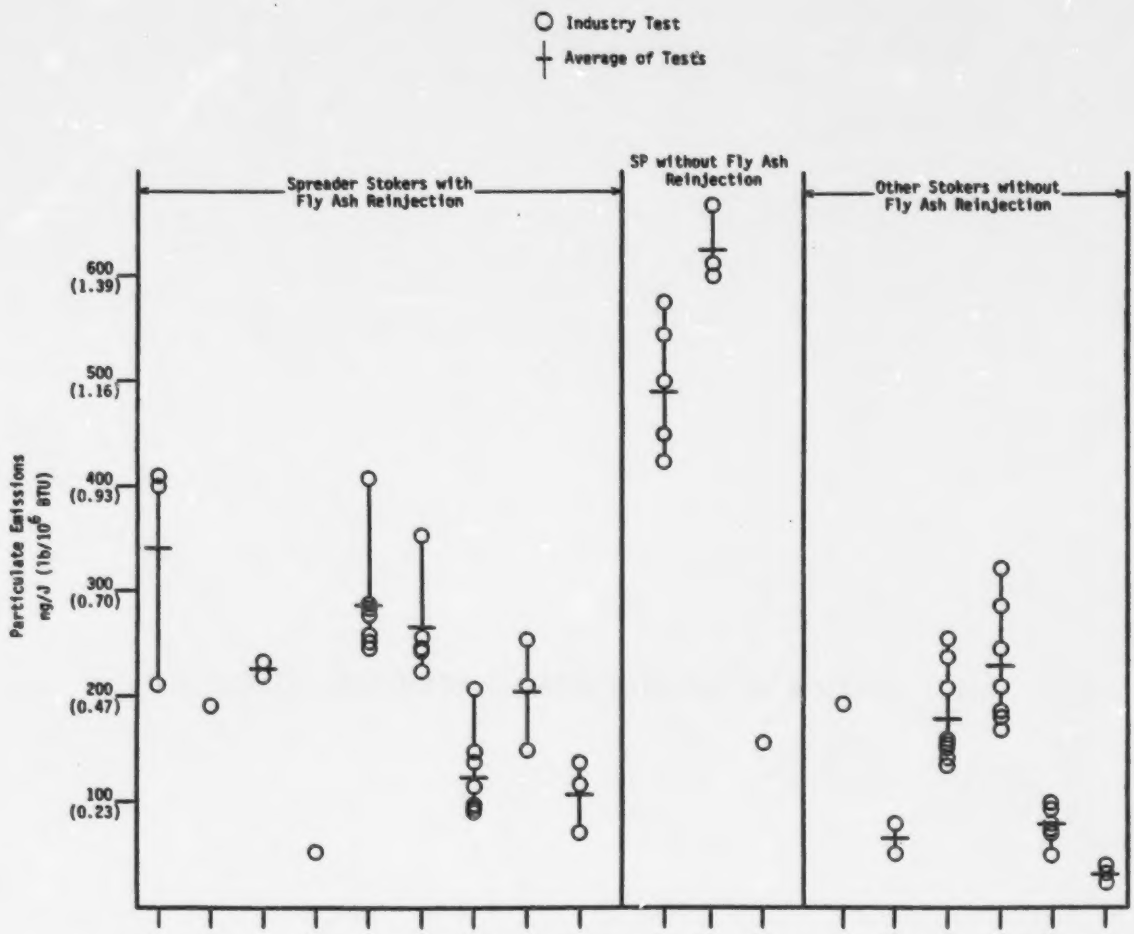
Test Number	One	Two	Three		Average
General Data					
Date	8-23-81	8-23-81	8-23-81		
Time					
Isokinetic Ratio (%)	96.7	95.9	98.6		97.1
Boiler Load (% of design)	53.6	52.0	51.0		52.2
Gas Data					
Excess Air (%)	117.9	117.9	117.9		117.9
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)					
Flow (dscfm)	18890	19245	18296		18810
Temperature (°C)	170	170	169		170
Temperature (°F)	337	337	336		337
Pressure (inches W.G.)					
Oxygen (%)	11.5	11.5	11.5		11.5
Particulate Emissions					
g/dnm^3					
gr/dscf					
ng/J	47.04	37.79	24.58		36.5
lb/10^6 Btu	0.1094	0.0879	0.0572		0.0848
Fuel Analysis					
Heating Value (kJ/kg)					
Heating Value (Btu/lb)					12914
% Ash					13.3
% Sulfur					1.44
Average Opacity (%)					

PLANT K2

TEST SUMMARY SHEETS (Particulates Only)[53]

Test Number	One	Two	Three		Average
General Data					
Date	9-13-81	9-13-81	9-13-81		
Time					
Isokinetic Ratio (%)	98.6	98.4	98.4		98.4
Boiler Load (% of design)	54.0	47.0	50.0		50.3
Gas Data					
Excess Air (%)	89.5	97.3	97.3		94.7
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)					
Flow (dscfm)	17,607	18,121	18,177		17,968
Temperature (°C)	176	176	176		176
Temperature (°F)	348	349	349		349
Pressure (inches W.G.)					
Oxygen (%)	8.9	8.0	8.0		8.3
Particulate Emissions					
g/dnm^3					
gr/dscf					
ng/J	32.31	20.92	19.62		24.28
lb/10^6 Btu	0.0751	0.0487	0.0456		0.0565
Fuel Analysis					
Heating Value (kJ/kg)					
Heating Value (Btu/lb)					12,952
% Ash					12.8
% Sulfur					2.20
Average Opacity (%)					

C.1.3 PARTICULATE EMISSION DATA FOR MECHANICAL COLLECTORS



Plant	AA	P	N	AA	N	P	AA	P	AA	UU	UU	AA	R	HH	R	R	HH	H
Boiler No.	G	–	–	G	–	–	G	–	G	–	–	G	–	–	–	–	–	–
Boiler Type[b]	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	SP	VG	CG	VG	VG	CG	U
Design Capacity (10^3 lb steam/hr)	75	200	300	75	300	200	75	200	75	160	160	75	90	70	90	90	70	35
Operating Capacity (% of Design)	16-17	47	37-59	57	60-74	73-79	76-86	81-100	97-102	55-60	59-60	98	45	48-50	61-69	79-89	73-103	77-90
Fuel Sulfur (Wt %)	0.92	0.84	0.77	0.75	0.91	0.92	0.72	0.90	0.90	–	–	0.75	2.23	1.82	2.26	1.89	1.65	0.57
Fuel Ash (Wt %)	7.3	8.9	7.2	8.3	5.3	7.4	7.5	8.0	6.8	–	–	8.3	8.2	9.0	8.1	7.2	7.0	8.1

Figure C.1.3-1. Mechanical collector emission data.[a]

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[a] All tests ordered from left to right by increasing operating capacity

[b] SP-spreader stoker, VG-vibrating grate stoker, CG-chain grate stoker, U-underfeed

Plant H

Particulate emission tests were conducted at Plant H to determine the degree of compliance with Ohio particulate emission codes. The tested unit (boiler no. 1) is a Babcock and Wilcox underfeed stoker with a rated capacity of 35,000 pounds of steam per hour. It is equipped with a Zurn Air Systems multiclone dust collector followed by an induced draft fan. The pressure drop across the multiclone collector is three inches of water. Tests were conducted in accordance with EPA Method 5. Boiler load averaged 82 percent of the rated capacity.[14]

PLANT H

TEST SUMMARY SHEETS (Particulates Only)[14]

Test Number	One	Two	Three	Average
General Data				
Date	7/26/78	7/26/78	7/26/78	
Time				
Isokinetic Ratio (%)	103.1	101.8	102.6	102.5
Boiler Load (% of design)	90.3	76.6	78.9	81.9
Gas Data				
Velocity (mps)	3.14	2.84	2.87	2.96
Velocity (fps)	10.3	9.3	9.4	9.7
Flow (dnm^3/min)	384.6	351.6	358.4	365.0
Flow (dscfm)	13581.7	12416.7	12565.7	12888.4
Temperature (°C)	217.1	214.3	209.3	213.6
Temperature (°F)	422.8	417.8	408.8	416.5
Pressure (inches W.C.)				
Moisture (%)	6.3	6.0	6.0	6.1
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	38.7	30.1	25.8	31.4
$lb/10^6$ Btu	0.09	0.07	0.06	0.073
Fuel Analysis				
Heating Value (kj/kg)				31710
Heating Value (Btu/lb)				13633
% Ash				8.11
% Sulfur				0.57
Average Opacity (%)	<5	<5	<5	

Plant N

The ABMA, DOE & EPA conducted tests at Plant N to determine boiler emissions and efficiency to help in the manufacture of more economical and environmentally satisfactory boilers and control equipment.

Plant N has two identical spreader stokers, each with a capacity of 300,000 pounds of steam per hour. Only one unit was tested. It is equipped with a mechanical collector and electrostatic precipitator in series.

All tests were conducted in accordance with EPA Method 5. Nine tests were conducted at the mechanical collector outlet and four at the ESP outlet. Results from tests conducted at the mechanical collector outlet are presented here.

Because boiler load varied from 37 to 85 percent of capacity, the series of 9 tests were divided into two sets of data. Low load tests (below 59%) and higher load tests (60 percent and above) are segregated and averaged separately in the following test summary sheets[2].

PLANT N
Low Load Tests
TEST SUMMARY SHEETS (Particulates Only)[2]

Test Number	One	Two	Three	MC Outlet Average
General Data				
Date	8/24	8/30		
Time				
Isokinetic Ratio (%)	108	99		104
Boiler Load (% of design)	37	59		48
Gas Data				
Velocity (mps)	9.10	11.44		10.3
Velocity (fps)	29.85	37.52		33.69
Flow (dnm^3/min)	1422.2	1706.0		1564.1
Flow (dscfm)	50220	60240		55230
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)	6.2	9.27		7.74
Particulate Emissions				
g/dnm^3	0.455	0.593		0.524
Gr/dscf	0.199	0.259		0.229
ng/J	230.9	220.2		225.6
lb/10^6 Btu	0.537	0.512		0.525
Fuel Analysis				
Heating Value (kj/kg)	24435	23188		23811
Heating Value (Btu/lb)	10505	9969		10237
% Ash	7.70	6.79		7.25
% Sulfur	0.92	0.62		0.77
Average Opacity (%)	3.1	2.5		28

PLANT N

Normal Load Tests

TEST SUMMARY SHEETS (Particulates Only)[2]

Test Number	One	Two	Three	Four
General Data				
Date	8/11/77	8/17/77	8/18/77	8/18/77
Time				
Isokinetic Ratio (%)	111.4	101	108	108
Boiler Load (% of design)	61	60	72	70
Gas Data				
Velocity (mps)	10.14	11.38	11.75	12.79
Velocity (fps)	33.25	37.34	38.54	41.95
Flow (dnm³/min)	1537.8	1709.4	1723.0	1860.6
Flow (dscfm)	54300	60360	60840	65700
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)	8.92	8.76	9.07	9.40
Particulate Emissions				
g/dnm³	0.7528	0.7253	0.8534	1.101
Gr/dscf	0.329	0.317	0.373	0.481
ng/J	250.26	277.78	283.8	407.64
lb/10⁶ Btu	0.582	0.646	0.660	0.948
Fuel Analysis				
Heating Value (kj/kg)	24533*	24533*	24628	24533*
Heating Value (Btu/lb)	10547	10547	10588	10547
% Ash	6.09	6.09	5.21	6.09
% Sulfur	0.93	0.93	1.02	0.93
Average Opacity (%)	2.9	3.0	6.5	19.7

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*This fuel analysis is not based on grab samples taken during the test. It is based on an average proximate analysis conducted on a coal stockpile.

PLANT N

Normal Load Tests

TEST SUMMARY SHEETS (Particulates Only)[2]

Test Number	Five	Six	Seven	MC Outlet Average
General Data				
Date	8/26	8/27	10/6	
Time				
Isokinetic Ratio (%)	95	102	101	104
Boiler Load (% of design)	74	73	74	69
Gas Data				
Velocity (mps)	12.82	12.55	13.95	12.2
Velocity (fps)	42.05	41.16	45.78	40.0
Flow (dnm^3/min)	1875.09	1819.8	1984.7	1754.4
Flow (dscfm)	66240	64260	70080	61950
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)	9.67	8.89	11.77	9.5
Particulate Emissions				
g/dnm^3	0.455	0.789	0.7665	0.658
Gr/dscf	0.199	0.315	0.335	0.356
ng/J	285.1	246.0	258	287
$lb/10^6$ Btu	0.663	0.572	0.600	0.667
Fuel Analysis				
Heating Value (kj/kg)	25074	24579	23638	24511
Heating Value (Btu/lb)	10780	10567	10158	10538
% Ash	4.49	6.13	3.14	5.32
% Sulfur	0.9	0.86	0.77	0.91
Average Opacity (%)	3.4	3.1	6.9	

Plant P

Plant P contains a Riley spreader stoker boiler with a rated capacity of 200,000 pounds of steam per hour. It is equipped with a mechanical dust collector and an electrostatic precipitator in series. Results from tests conducted at the mechanical collector outlet are presented here.

The mechanical dust collector is a UOP Design 104 with 140 ten-inch tubes. Fly ash from the dust collector hopper and economizer was reinjected back into the boiler during all tests. Nine tests were performed during which the boiler fired a Kentucky Cumberland coal. Boiler load during testing averaged 78 percent.[3]

Because boiler load varied from 47 to 100 percent of capacity, the series of 9 tests were divided into three sets of data: high, medium and low load tests. The data in each set are averaged and presented separately in the summary figures at the beginning of this section. One low load test (47%) is presented alone, while a second set consists of all tests conducted between loads of 73 to 79 percent of capacity. The third set consists of all tests run between 81 to 100 percent of capacity.

PLANT P

Multiclone Outlet

TEST SUMMARY SHEETS (Particulates Only)^3

Low Load Test

Test Number	One	Two	Three	Average
General Data				
Date				
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	47			
Gas Data				
Velocity (mps)	7.43			
Velocity (fps)	24.39			
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.455			
Gr/dscf	0.199			
ng/J	192			
$lb/10^6$ Btu	0.446			
Fuel Analysis				
Heating Value (kj/kg)	31339			
Heating Value (Btu/lb)	13485			
% Ash	8.85			
% Sulfur	0.84			
Average Opacity (%)				

PLANT P
Medium Load Tests
TEST SUMMARY SHEETS (Particulates Only)[3]

Test Number	One	Two	Three	Four
General Data				
Date				
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	73	75	73	79
Gas Data				
Velocity (mps)	10.31	11.95	9.79	11.01
Velocity (fps)	33.82	39.23	32.11	31.12
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.618	0.746	0.602	0.670
Gr/dscf	0.270	0.326	0.263	0.293
ng/J	241	357	223	254
$lb/10^6$ Btu	0.561	0.830	0.518	0.591
Fuel Analysis				
Heating Value (kj/kg)	30147	30470	31221	30830
Heating Value (Btu/lb)	12972	13111	13434	13266
% Ash	8.22	8.83	5.92	5.83
% Sulfur	1.06	1.05	0.93	0.68
Average Opacity (%)				

PLANT P

Medium Load Test

TEST SUMMARY SHEETS (Particulates Only) [3]

Test Number	Five	Average		
General Data				
Date				
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	75	75		
Gas Data				
Velocity (mps)	9.23	10.46		
Velocity (fps)	30.28	33.31		
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.713	0.670		
Gr/dscf	0.311	0.293		
ng/J	242	263		
lb/10^6 Btu	0.563	0.613		
Fuel Analysis				
Heating Value (kj/kg)	30479	30629		
Heating Value (Btu/lb)	13115	13180		
% Ash	8.00	7.36		
% Sulfur	0.87	0.92		
Average Opacity (%)				

PLANT P

High Load Tests

TEST SUMMARY SHEETS (Particulates Only)[3]

Test Number	One	Two	Three	Average
General Data				
Date				
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	81	99	100	93
Gas Data				
Velocity (mps)	10.85	13.50	13.33	12.56
Velocity (fps)	35.60	44.29	43.72	41.20
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.387	0.584	0.725	0.565
Gr/dscf	0.169	0.255	0.317	0.247
ng/J	147	209	256	204
lb/10^6 Btu	0.343	0.485	0.596	0.475
Fuel Analysis				
Heating Value (kj/kg)	30951	30391	30033	30458
Heating Value (Btu/lb)	13318	13077	12923	13106
% Ash	5.81	7.60	10.66	8.02
% Sulfur	0.87	0.91	0.91	0.90
Average Opacity (%)				

Plant R

Plant R contains a Babcock and Wilcox vibrating grate stoker (Boiler D) equipped with a UOP multiclone dust collector. Boiler D has a rated capacity of 90,000 pounds of steam per hour. Sixteen particulate emission tests were conducted at this unit using three different coal types.

This series of tests is divided into three sets of data: low, medium and high load tests. The data in each set are averaged and presented separately from the other sets. Overfire air pressure was varied at low, medium and high boiler loadings. One test was conducted at low load with overfire air pressure at 10 inches of water. Eight medium load tests were conducted with overfire air pressure varying from 5 to 13 inches of water. Six tests were conducted at high load. Overfire air pressure varied from 7 to 15 inches of water. All tests were carried out in accordance with EPA Method 5.[15] Opacity was determined with a transmissometer.

PLANT R

Low Load Test

TEST SUMMARY SHEETS (Particulates Only)[15]

Test Number	One	Two	Three	Average
General Data				
Date	8/29			
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	45			
Overfire Air Pressure (inches H_2O)	10			
Gas Data				
Velocity (mps)	3.30			
Velocity (fps)	10.82			
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.316			
Gr/dscf	0.138			
ng/J	196.08			
$lb/10^6$ Btu	0.456			
Fuel Analysis				
Heating Value (kj/kg)	30396			
Heating Value (Btu/lb)	13068			
% Ash	8.24			
% Sulfur	2.23			
Average Opacity (%)	7			

PLANT R

Medium Load Tests

TEST SUMMARY SHEETS (Particulates Only)[15]

Test Number	One	Two	Three	Four
General Data				
Date	8/3	8/15	8/22	8/18
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	69	64	63	65
Overfire Air Pressure (in. H_2O)	6	6	15	5
Gas Data				
Velocity (mps)	5.67	4.07	4.72	4.19
Velocity (fps)	18.59	13.36	15.5	13.74
Flow (dnm³/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm³	0.288	0.476	0.384	0.325
Gr/dscf	0.126	0.208	0.168	0.142
ng/J	152.65	239.57	209.84	159.96
lb/10⁶ Btu	0.355	0.557	0.488	0.372
Fuel Analysis				
Heating Value (kj/kg)	29854	30426	30187	30317
Heating Value (Btu/lb)	12835	13081	12978	13034
% Ash	9.26	8.08	9.0	8.83
% Sulfur	2.54	2.79	2.57	2.85
Average Opacity (%)	-	30	12	12

PLANT R

Medium Load Tests

TEST SUMMARY SHEETS (Particulates Only)[15]

Test Number	Five	Six	Seven	Eight	Average
General Data					
Date	8/23	8/31	9/13	9/22	
Time					
Isokinetic Ratio (%)					
Boiler Load (% of design)	66	63	64	61	64
Overfire Air Pressure (in. H_2O)	10	10	10	13	9.4
Gas Data					
Velocity (mps)	5.21	4.28	4.46	4.17	4.60
Velocity (fps)	17.09	14.03	14.62	13.67	1508
Flow (dnm^3/min)					
Flow (dscfm)					
Temperature (°C)					
Temperature (°F)					
Pressure (inches W.G.)					
Moisture (%)					
Particulate Emissions					
g/dnm^3	0.270	0.291	0.286	0.469	0.349
gr/dscf	0.118	0.127	0.125	0.205	0.152
ng/J	141.04	152.22	137.17	255.85	181.03
$lb/10^6$ Btu	0.328	0.354	0.319	0.595	0.421
Fuel Analysis					
Heating Value (kJ/kg)	30433	30282	31685	31068	30532
Heating Value (Btu/lb)	13084	13019	13627	13357	13127
% Ash	8.65	8.13	5.89	6.96	8.1
% Sulfur	2.59	2.50	1.11	1.11	2.26
Average Opacity (%)	12	12	12	11	13

PLANT R

High Load Tests

TEST SUMMARY SHEETS (Particulates Only)[15]

Test Number	One	Two	Three	Four
General Data				
Date	9/6	9/8	9/12	9/12
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	87	89	87	88
Overfire Air pressure	10	7	7	15
Gas Data				
Velocity (mps)	5.29	5.42	4.56	4.95
Velocity (fps)	17.37	17.77	14.97	16.25
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.613	0.485	0.753	0.410
Gr/dscf	0.268	0.212	0.329	0.179
ng/J	287.8	210.7	324.22	182.32
$lb/10^6$ Btu	0.667	0.490	0.754	0.424
Fuel Analysis				
Heating Value (kj/kg)	29854	29864	31034	32166
Heating Value (Btu/lb)	12935	12839	13342	13829
% Ash	9.14	9.57	6.86	4.92
% Sulfur	2.82	2.94	2.04	1.15
Average Opacity (%)	19	29	35	19

PLANT R

High Load Tests

TEST SUMMARY SHEETS (Particulates Only)[15]

Test Number	Five	Six	Seven	Average
General Data				
Date	8/16	9/14	9/15	
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	86	87	79	86
Overfire Air pressure	10	10	normal	9.8
Gas Data				
Velocity (mps)	4.90	5.22	5.51	5.12
Velocity (fps)	16.07	17.14	18.09	16.81
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.563	0.403	0.403	0.519
Gr/dscf	0.246	0.176	0.176	0.227
ng/J	246.82	168.99	181.03	228.84
$lb/10^6$ Btu	0.574	0.393	0.421	0.532
Fuel Analysis				
Heating Value (kj/kg)	30317	31845	31778	30979
Heating Value (Btu/lb)	13034	13691	13662	13333
% Ash	8.47	5.66	5.99	7.23
% Sulfur	2.44	0.86	0.98	1.89
Average Opacity (%)	23	32	19	25

Plant AA

Plant AA contains a Zurn spreader stoker (Boiler G) rated at 75,000 pounds of steam per hour. The overfire air system consists of three rows of air jets, one lower row on the front wall and an upper and lower row on the rear wall. Fly ash is reinjected. Exhaust gas from this boiler is vented to a UOP mechanical dust collector.

Fifteen particulate emission tests were conducted at this site in accordance with EPA Method 5. Boiler capacity varied from 15% to 100% of design capacity. The series of 15 tests are divided into four sets of data: low, medium, intermediate and high load tests. The data in each set are averaged and presented separately from the other sets.

Particulate emissions were well above average during tests where boiler loads averaged 17% of design (low load tests). During test number 10 fly ash was not reinjected and the particulate emission rate (.364 lb/10^6 Btu) was above average. Two tests (numbers 2 and 15) were conducted under low overfire air conditions. No effect on particulate emission rate was shown. All other tests were conducted under normal conditions except test number 5 in which boiler load was 57% of capacity. The lowest particulate emission rate (.129 lb/10^6 Btu) was experienced during this test.[16]

PLANT AA

Low Load Tests

TEST SUMMARY SHEETS (Particulates Only)[16]

Test Number	One	Two *	Three	Average
General Data				
Date				
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	16	17	17	17
Gas Data				
Velocity (mps)	8.75	10.60	8.40	9.24
Velocity (fps)	28.7	34.78	27.57	30.33
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.435	0.476	0.229	0.38
Gr/dscf	0.190	0.208	0.100	0.17
ng/J	401.19	409.79	212.85	341.4
lb/10^6 Btu	0.933	0.953	0.495	0.793
Fuel Analysis				
Heating Value (kj/kg)	29933	32238	29803	30658
Heating Value (Btu/lb)	12869	13860	12813	13181
% Ash	8.32	6.56	6.95	7.28
% Sulfur	0.75	1.31	0.69	0.92
Average Opacity (%)				

* No Flyash Reinjection

PLANT AA

Medium Load Test

TEST SUMMARY SHEETS (Particulates Only)[16]

Test Number	One	Two	Three	Average
General Data				
Date				
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	57			
Gas Data				
Velocity (mps)	15.33			
Velocity (fps)	50.28			
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.105			
Gr/dscf	0.046			
ng/J	55.47			
$lb/10^6$ Btu	0.129			
Fuel Analysis				
Heating Value (kj/kg)	29933			
Heating Value (Btu/lb)	12869			
% Ash	8.32			
% Sulfur	0.75			
Average Opacity (%)				

PLANT AA

Intermediate Load Tests

TEST SUMMARY SHEETS (Particulates Only)[16]

Test Number	One	Two	Three*	Four*
General Data				
Date				
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	76	77	78	80
Gas Data				
Velocity (mps)	18.42	19.17	19.08	19.09
Velocity (fps)	60.42	62.88	62.61	62.64
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.323	0.195	0.279	0.213
Gr/dscf	0.141	0.085	0.122	0.093
ng/J	137.6	95.03	111.8	94.6
$lb/10^6$ Btu	0.320	0.221	0.260	0.220
Fuel Analysis				
Heating Value (kj/kg)	29803	29803	29803	29933
Heating Value (Btu/lb)	12813	12813	12813	12869
% Ash	6.95	6.95	6.95	8.32
% Sulfur	0.69	0.69	0.69	0.75
Average Opacity (%)				

* Low overfire air

PLANT AA

Intermediate Load Tests

TEST SUMMARY SHEETS (Particulates Only)[16]

Test Number	Five	Six	Seven	Average
General Data				
Date				
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	82	85	86	81
Gas Data				
Velocity (mps)	20.61	19.27	20.08	19.32
Velocity (fps)	67.62	63.21	65.87	63.61
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (incnes W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.311	0.195	0.458	0.282
Gr/dscf	0.136	0.085	0.200	0.123
ng/J	143.62	95.46	208.12	126.6
$lb/10^6$ Btu	0.334	0.222	0.484	0.294
Fuel Analysis				
Heating Value (kj/kg)	29803	29933	29933	29859
Heating Value (Btu/lb)	12813	12869	12869	12837
% Ash	6.95	8.32	8.32	7.54
% Sulfur	0.69	0.75	0.75	0.72
Average Opacity (%)				

PLANT AA

High Load Tests

TEST SUMMARY SHEETS (Particulates Only)[16]

Test Number	One	Two *	Three	Four	Average
General Data					
Date					
Time					
Isokinetic Ratio (%)					
Boiler Load (% of design)	97	98	100	102	99
Gas Data					
Velocity (mps)	21.63	20.93	20.78	20.00	20.84
Velocity (fps)	70.96	68.65	68.19	65.63	68.36
Flow (dnm^3/min)					
Flow (dscfm)					
Temperature (°C)					
Temperature (°F)					
Pressure (inches W.C.)					
Moisture (%)					
Particulate Emissions					
g/dnm^3	0.325	0.362	0.192	0.275	0.289
Gr/dscf	0.142	0.158	0.084	0.120	0.126
ng/J	137.6	156.52	71.38	117.82	120.83
lb/10^6 Btu	0.320	0.364	0.166	0.274	0.281
Fuel Analysis					
Heating Value (kj/kg)	29803	29933	32238	29803	30444
Heating Value (Btu/lb)	12813	12869	13860	12813	13089
% Ash	6.95	8.32	6.56	6.95	7.20
% Sulfur	0.69	0.75	1.31	0.69	0.86
Average Opacity (%)					

* No fly ash reinjection

Plant HH

Plant HH contains a Keeler traveling chaingrate stoker boiler with a rated capacity of 70,000 pounds of steam per hour. There are two rows of overfire air (OFA) jets on the front wall. At maximum flow the OFA pressure is about 10 inches of water. Particulate emissions are controlled by a mechanical dust collector.

Eight tests were conducted according to EPA Method 5 to determine the particulate emission rate. Overfire air pressure was varied from 0.8 to 7.8 inches of water. Boiler load ranged from 48 to 100 percent of rated capacity.[17] The series of 8 tests were divided into two sets of data: low and high load tests. The data in each set are averaged and presented separately from the other sets.

PLANT HH

Low Load Tests
TEST SUMMARY SHEETS (Particulates Only)[17]

Test Number	One	Two	Three	Average
General Data				
Date	6/3/70	6/16/79		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	48.2	49.6		48.9
Over fire Air pressure (in. H_2O)	0.8	2.3		1.55
Gas Data				
Velocity (mps)	10.35	5.92		8.14
Velocity (fps)	33.96	19.41		26.69
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.103	0.124		0.11
Gr/dscf	0.045	0.054		0.050
ng/J	49.45	79.55		64.50
$lb/10^6$ Btu	0.115	0.185		0.150
Fuel Analysis				
Heating Value (kj/kg)	31569	29101		30335
Heating Value (Btu/lb)	13572	12511		13042
% Ash	6.31	11.76		9.04
% Sulfur	1.06	2.57		1.82
Average Opacity (%)				

PLANT HH

High Load Tests

TEST SUMMARY SHEETS (Particulates Only)[17]

Test Number	One	Two	Three	Four
General Data				
Date	6/15/79	6/4/69	6/14/79	6/20/79
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	73.1	73.8	84.9	97.1
Overfire Air Pressure (in.H_2O)	2.5	3.5		7.7
Gas Data				
Velocity (mps)	6.53	16.30	8.79	9.67
Velocity (fps)	21.42	53.47	28.85	31.73
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.108	0.149	0.153	0.204
Gr/dscf	0.047	0.065	0.067	0.089
ng/J	49.02	80.84	71.81	96.32
lb/10^6 Btu	0.114	0.188	0.167	0.224
Fuel Analysis				
Heating Value (kj/kg)	32552	31180	31106	30473
Heating Value (Btu/lb)	13995	13405	13373	13101
% Ash	5.31	7.06	7.11	8.23
% Sulfur	1.40	1.52	1.68	1.82
Average Opacity (%)				

PLANT HH

High Load Tests

TEST SUMMARY SHEETS (Particulates Only)[17]

Test Number	Five	Six	Seven	Average
General Data				
Date	6/13/79	6/12/79		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	98.6	102.6		88.4
Overfire Air Pressure (in. H_2O)	4.0	7.8		5.1
Gas Data				
Velocity (mps)	9.66	19.10		11.68
Velocity (fps)	31.69	62.67		38.31
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.179	0.211		0.167
Gr/dscf	0.078	0.092		0.073
ng/J	78.26	98.04		79.05
$lb/10^6$ Btu	0.182	0.228		0.184
Fuel Analysis				
Heating Value (kj/kg)	32485	29238		31172
Heating Value (Btu/lb)	13966	12570		13402
% Ash	4.18	10.22		7.02
% Sulfur	1.30	2.18		1.65
Average Opacity (%)				

Plant UU

Plant UU has a Babcock and Wilcox stoker with a rate capacity of 160,000 pounds of steam per hour. It is equipped with a multiclone mechanical dust collector.

Nine particulate emission tests were conducted according to EPA Method 5. One set of tests were conducted under low excess air conditions while the second set were conducted under normal excess air conditions. Boiler load averaged 59 percent of design capacity for the normal excess air tests and 58 percent for the low excess air tests. Opacity readings were obtained using continuous transmissometers. Opacity averaged 25 and 32 percent for the low and normal excess air tests, respectively.

PLANT UU

Low Excess Air Tests

TEST SUMMARY SHEETS (Particulates Only)[18]

Test Number	One	Two	Three	Four
General Data				
Date				
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	59	60	55	59
O_2%	8.8	8.7	8.8	8.5
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)	330	323	314	326
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.94	1.00	1.10	1.30
Gr/dscf	0.410	0.439	0.481	0.569
ng/J	425	450	500	575
lb/10^6 Btu	0.99	1.05	1.16	1.34
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)	25	25	25	30

PLANT UU
Low Excess Air Tests
TEST SUMMARY SHEETS (Particulates Only)[18]

Test Number	Five	Six	Seven	Average
General Data				
Date	8/13/79	8/14/79		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	58	59		58.5
O_2%	8.5	8.4		8.6
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)	318	308		320
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	1.02	1.24		1.10
Gr/dscf	0.446	0.540		0.481
ng/J	450	543		491
lb/10^6 Btu	1.05	1.26		1.14
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)	25	25		25

PLANT UU

Normal Excess Air Tests
TEST SUMMARY SHEETS (Particulates Only)[18]

Test Number	One	Two	Three	Average
General Data				
Date	8/11/79	8/11/79		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	59	60	59	59
O_2 %	8.9	9.5	9.0	9.1
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)	315	315	314	315
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	1.46	1.27	1.31	1.35
Gr/dscf	0.637	0.555	0.571	0.588
ng/J	667	612	600	626
$lb/10^6$ Btu	1.55	1.42	1.40	1.46
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)	35	35	25	32

Plant ZZ

A compliance test was performed on plant ZZ's number two oil-fired steam boiler for the State of Maryland, Division of Compliance. The boiler has a rated capacity of 55,000 lbs/hr and was run at 37,000 lbs/hr for the test or 67 percent of the capacity. Emissions from the boiler are controlled by a mechanical collector, a V6M Breslove Dust Collector.

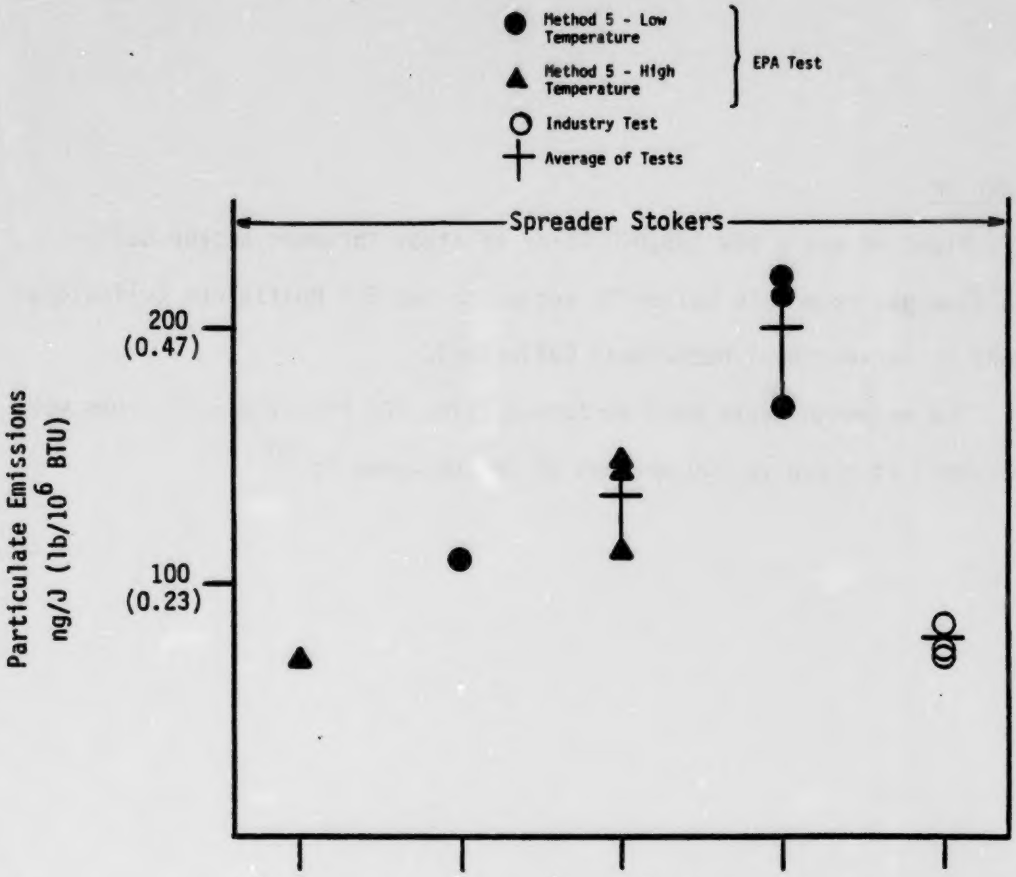
Two tests were performed using basically an EPA Method 5 except the filter and probe temperature were at 300 F rather than 250°F.[19]

PLANT ZZ

TEST SUMMARY SHEETS (Particulates Only)[19]

Test Number	One	Two	Three	Average
General Data				
Date	12/6/73	12/7/73		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	67	67		67
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)	310	308		309
Flow (dscfm)	10,955	10,867		10911
Temperature (°C)	267	269		268
Temperature (°F)	513	517		515
Pressure (inches W.C.)				
Moisture (%)	9.71	10.10		9.9
Particulate Emissions				
g/dnm^3	0.0263	0.0240		0.025
Gr/dscf	0.0115	0.0105		0.011
ng/J	9.46	8.60		9.03
lb/10^6 Btu	0.022	0.020		0.021
Fuel Analysis				
Heating Value (kj/kg)	43,726	43,726		43726
Heating Value (Btu/lb)	18,800	18,800		18800
% Ash	nil	nil		nil
% Sulfur	.906	0.906		0.906
Average Opacity (%)				

C.1.4 PARTICULATE EMISSION DATA FOR DUAL MECHANICAL COLLECTORS



Plant	XX	XX	XX	XX	PP
Boiler Number	3	3	3	3	-
Design Capacity (10^3 lb steam/hr)	75	75	75	75	145
Operating Capacity (% of Design)	71	71	96-98	96-98	~100
Fuel Sulfur (Wt %)	2.86	2.86	2.70	2.70	0.74
Fuel Ash (Wt %)	8.7	8.7	7.6	7.6	6.4
Fly Ash Reinjection	No	No	No	No	No

Figure C.1.4-1. Dual mechanical collector emission data.[a]

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[a] All tests ordered from left to right by increasing operating capacity

PLANT PP

Plant PP has a B&W 145,000 lb/hr of steam spreader stoker boiler. The flue gas from this boiler is vented to two 6UP Multiclone Collectors (UOP) in series (Dual Mechanical Collector).

The emission tests were performed using EPA Method 5. All runs were performed at close to 100 percent of design capacity.[20]

PLANT PP

TEST SUMMARY SHEETS (Particulates Only)[20]

Test Number	One	Two	Three	Average
General Data				
Date	11/30/77	12/1/77	12/1/77	
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	~100	~100	~100	~100
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm³/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm³				
Gr/dscf				
ng/J	74.0	84.7	72.7	77.0
lb/10⁶ Btu	0.172	0.197	0.169	0.179
Collection Efficiency, %	92.6	92.8	95.8	93.7
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash	5.87	7.20	6.13	6.40
% Sulfur	0.61	0.95	0.66	0.74
Average Opacity (%)				

Plant XX

Stack testing of Boiler No. 3, a coal-fired spreader stoker, was conducted by EPA at Plant XX to determine the quantity of boiler emissions and collection device efficiency. The boiler has a rated capacity of 93 million Btu/hr (thermal input) to produce 75,000 lb/hr of steam. The boiler emissions are controlled by a dual multi-tube cyclone dust collector (dual mechanical collector).

The testing was conducted using EPA Method 5 at two different sample box temperatures. In Method 5 the temperature of the filter and probe on the sampling train is normally maintained at 120°C (248°F). In a simultaneous Method 5 test at Plant XX, the other sampling train was maintained at 177°C (350°F) to avoid collection of condensed SO_3. The results of the two tests are averaged and presented separately.

Four tests were conducted with the boiler running near 100 percent of capacity during the first three tests and 75 to 80 percent during the fourth run. The cyclone pressure drop for tests 1 through 4 was 6.5, 6.6, 6.6 and 4.0 inches W.G. for an average of 5.9 inches.[21]

Air flow rates were higher than normal throughout the testing period at Plant XX. This conclusion was based on previous tests conducted on this boiler and a mass balance analysis. Estimates show that as much as 30 percent of the total flow was due to air leaking in through the collector doors and sampling ports. This excess flow may affect the performance of the dual mechanical collector. In addition, plant personnel indicate that hopper ash reintrainment may occur when air leaks in through the collector doors.[*] Because of the air leaking in and the potential for hopper ash reintrainment, this data was not included in Chapter 4.

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[*] Memo and attachments from Burt, R. to Sedman, C.B., EPA. May 30, 1980. Memo regarding test results from DuPont at Parkersburg, West Virginia.

PLANT XX
Method 5*
TEST SUMMARY SHEETS (Particulates Only)[21]

Test Number	One	Two	Three	Four	Average
General Data					
Date	12/16/80	12/16/80	12/17/80		
Time					
Isokinetic Ratio (%)	103	104	103	107	104
Boiler Load (% of design)	96.3	97.5	95.7	71.3	90.2
Gas Data					
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)	829	803	849	626	777
Flow (dscfm)	29257	28343	29964	22104	27417
Temperature (°C)	156	155	156	146	153
Temperature (°F)	313	312	313	295	308
Pressure (inches W.C.)	7.7	7.7	7.9	4.8	7.0
Moisture (%)	4.74	5.54	5.03	5.36	5.17
Particulate Emissions					
g/dnm^3	0.3908	0.3520	0.3471	0.2056	0.3239
Gr/dscf	.1707	.1538	0.1516	0.0898	0.1415
ng/J	217.6	168.7	212.6	109.0	177.0
lb/10^6 Btu	0.506	0.392	0.494	0.253	0.411
Fuel Analysis					
Heating Value (kj/kg)	31866	32796	32098	31866	32157
Heating Value (Btu/lb)	13700	14100	13880	13700	13825
% Ash	7.60	7.72	7.58	8.68	7.90
% Sulfur	2.69	2.70	2.72	2.86	2.74
Average Opacity (%)	17.1	17.1	21.9	21.9	19.5 19.5

*Sample box temperature - 120°C (248°F).

PLANT XX

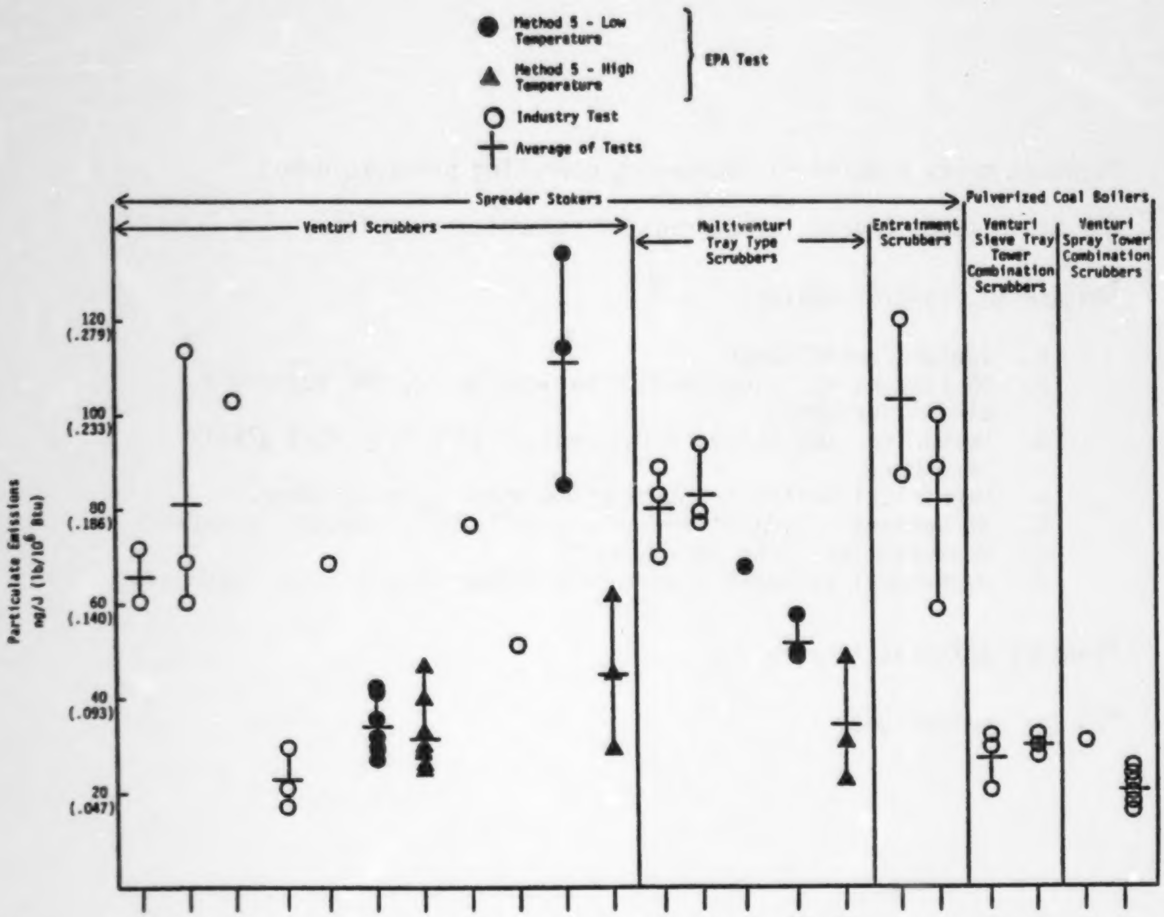
Method 5*

TEST SUMMARY SHEETS (Particulates Only)[21]

Test Number	One	Two	Three	Four	Average
General Data					
Date	12/16/80	12/16/80	12/17/80	12/17/80	
Time					
Isokinetic Ratio (%)	106	106	104	101	104
Boiler Load (% of design)	96.3	97.5	95.7	71.3	90.2
Gas Data					
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)	830	805	848	630	778
Flow (dscfm)	29308	28425	29939	22260	27483
Temperature (°C)	156	156	156	146	154
Temperature (°F)	313	313	313	295	309
Pressure (inches W.C.)	7.7	7.7	7.9	4.8	7.0
Moisture (%)	4.54	5.15	5.13	4.80	4.91
Particulate Emissions					
g/dnm^3	0.2674	0.234	0.2323	0.1370	0.2177
Gr/dscf	0.1168	0.1022	0.1015	0.0599	0.0951
ng/J	148.9	112.1	142.3	72.6	119.0
lb/10^6 Btu	0.346	0.261	0.331	0.169	0.277
Fuel Analysis					
Heating Value (kj/kg)	31866	32796	32098	31866	32157
Heating Value (Btu/lb)	13700	14100	13800	13700	13825
% Ash	7.60	7.72	7.58	8.68	7.90
% Sulfur	2.69	2.70	2.72	2.86	2.74
Average Opacity (%)	17.1	17.1	21.9	21.9	19.5

*Sample box temperature - 177°C (350°F).

C.1.5 PARTICULATE EMISSION DATA FOR WET SCRUBBERS



Plant	QQ	QQ	QQ	L	MM	LL	LL	MM	LL	LL	LL	M	M	SS	AAA	AAA	O	O	OO	OO	TT	TT
Boiler No.	4	5	5	3	2	20	20	3	19	19	19	1	4	3	1	1	3	2	-	-	-	-
Design Capacity (10^3 lb steam/hr)	-	-	-	100	-	-	-	-	-	-	-	100	60	60	100	100	100	80	-	-	-	-
(10^6 Btu/hr)	202	202	202	-	295	236	236	295	236	236	236	-	-	-	-	-	-	-	137	137	100	100
Operating Capacity (% of Design)	80-100	80-95	95	93-97	75	85-91	85-91	75	100	73	73	86-92	79-83	81	92	92	80-100	88	100	100	100	100
Emission Controls[b]	5	5	5	2	7	7	7	7	7	7	7	3	3	3	3	3	4	4	6	6	1	1
Scrubber Pressure Drop (in H_2O guage) Design	22	22	22	10	17	17	17	17	17	17	17	13	13	13	13	13	12	12	-	-	-	-
Operating	8	8	8	10	16	17.3	17.3	17.5	18.1	19.3	19.3	7.5	7.5	7.5	7.5	7.5	12	12	12/45[c]	17/45[c]	3[d]	9[d]
Design L/G (gpm/10^3 acfm)	11.4	11.4	11.4	-	10	10	10	10	10	10	10	20	20	-	-	-	-	-	20	20	4	17
Fuel Sulfur (wt %)	2.4-3.4	2.4-3.4	2.4-3.4	0.8	2.4-3.4	2.54	2.54	2.4-3.4	2.4-3.4	2.6	2.6	2.3	2.4	2.14	1.33	1.33	2.33	2.33	3.5	3.5	3.9	3.9
Fuel Ash (wt %)	10	10	10	7.2	10	10.4	10.4	10	10	11.4	11.4	9.4	8.0	5	4.4	4.4	10.5	9.9	12.3	12.3	14.7	14.7
Fly Ash Reinjection	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No

Figure C.1.5-1. Emission data for wet scrubbers.[a]

[a] Venturi tests ordered by increasing operating pressure drop.

All other tests ordered by decreasing percent ash in fuel.

[b] PM and SO_2 control devices.

1. Venturi/spray tower
2. 95 percent efficient mechanical collector, FMC venturi dual alkali scrubber.
3. Mechanical collector, multi-venturi flex tray dual alkali scrubber.
4. Mechanical collector, Zurn entrainment type scrubber.
5. 80 percent efficient mechanical collector, venturi scrubber.
6. Venturi/sieve tray scrubber.
7. Mechanical collector, venturi scrubber with cyclonic separators.

[c] Venturi Δp/sieve tray Δp.

[d] Δp for venturi only.

Plant L

Particulate emission tests at Plant L were conducted on a spreader stoker unit, boiler no. 3. Boiler no. 3 has a rated capacity of 100,000 pounds of steam per hour. The boiler is equipped with a Western Precipitator Multiclone mechanical dust collector which is vented to a venturi scrubber using a sodium scrubbing solution for combined SO_2/PM removal. Boiler no. 3's mechanical collector is designed for 95 percent particulate removal. The design air flow through the scrubber is 56,000 acfm at 390°F. Operating pressure drop is 10 inches of water. All tests were conducted according to EPA Method 5. The boiler operated at an average of 95 percent of design load with an average particulate emission rate of 0.05 pounds per million Btu.[22]

PLANT L

Boiler #3

TEST SUMMARY SHEETS (Particulates Only)[22]

Test Number	One	Two	Three	Average
General Data				
Date	9/18/75	9/22/75	9/23/75	
Time	10:30-14:30	10:50-14:30	9:00-13:00	
Isokinetic Ratio (%)	105	102	100	120
Boiler Load (% of design)	97	94	92.5	94.5
Operating ΔP (in H_2O gauge)	10	10	10	10
Gas Data				
Velocity (mps)	18.03	18.19	18.57	18.26
Velocity (fps)	59.15	59.68	60.93	59.92
Flow (dnm^3/min)	847.3	1119.6	899.8	955.6
Flow (dscfm)	29917	39535	31774	33742
Temperature (°C)	53.9	52.2	52.2	52.2
Temperature (°F)	129	126	126	127
Pressure (inches W.C.)	0	0	0	0
Moisture (%)	16	13	13	14
Particulate Emissions				
g/dnm^3	0.046	0.069	0.046	0.046
Gr/dscf	0.02	0.03	0.02	0.02
ng/J	17.2	30.1	21.5	22.9
$lb/10^6$ Btu	0.04	0.07	0.05	0.05
Fuel Analysis				
Heating Value (kj/kg)	29419	29912	30164	29831
Heating Value (Btu/lb)	12648	12860	12968	12825
% Ash	8.1	7.7	5.7	7.2
% Sulfur	0.7	1.0	0.8	0.8
Average Opacity (%)				

*Assuming design load of 100,000 pounds of steam per hour.

Plant M

Two of the four spreader stoker boilers at Plant M were tested to determine compliance with the Ohio State EPA Standards. The tested units (numbers 1 and 4) are each equipped with a mechanical collector and a Koch Multiventuri Flexitray scrubber for combined SO_2/PM removal in series. Both scrubbers have a design liquid to gas ratio of 20 gal/10^3 acfm. Unit number 1, an Erie City Iron Works boiler, has a rated capacity of 100,000 pounds of steam per hour. The Wickers boiler, unit number 4, has a rated capacity of 60,000 pounds of steam per hour.

Three tests were conducted at each unit. Boiler load during testing averaged 78.9% of capacity at unit number 4 and 89.1% of capacity at unit number 1. The emission rate was found to be above the State limit of 0.13 pounds per million Btu and above the design limit of 0.10 pounds per million Btu. The problem was believed to be caused by mist carryover from the eliminator contributing to high emission rates.[23]

PLANT M

Boiler #1

TEST SUMMARY SHEETS (Particulates Only)[23]

Test Number	One	Two	Three	Average
General Data				
Date	12/79			
Time				
Isokinetic Ratio (%)	94.5	94	91	93.2
Boiler Load (% of design)	88.7	86.4	92.3	89.1
Operating ΔP (inch H_2O)				7.5
Gas Data				
Velocity (mps)	12.55	12.80	11.91	12.42
Velocity (fps)	41.17	42.0	39.07	40.75
Flow (dnm^3/min)	875.2	895.6	850.7	873.8
Flow (dscfm)	30,903	31,624	30,037	30855
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)	0.18	0.18	0	0.12
Moisture (%)	11.5	11.4	11.2	11.4
Particulate Emissions				
g/dnm^3	0.1762	0.1396	0.1945	0.1701
Gr/dscf	0.077	0.061	0.085	0.074
ng/J	83.42	69.66	88.58	80.41
lb/10^6 Btu	0.194	0.162	0.206	0.187
Fuel Analysis				
Heating Value (kj/kg)	29056	28959	29373	29129
Heating Value (Btu/lb)	12492	12450	12628	12523
% Ash	8.6	9.1	10.4	9.4
% Sulfur	2.4	2.2	2.4	2.3
Average Opacity (%)				

PLANT M

Boiler #4

TEST SUMMARY SHEETS (Particulates Only)[23]

Test Number	One	Two	Three	Average
General Data				
Date				
Time				
Isokinetic Ratio (%)	99.8	98.6	97.4	98.6
Boiler Load (% of design)	82.5	79.1	75.2	78.9
Operating ΔP (inch H_2O)				7.5
Gas Data				
Velocity (mps)	11.95	11.81	11.48	11.75
Velocity (fps)	39.2	38.75	37.67	38.54
Flow (dnm^3/min)	778.7	777.7	756.9	771.1
Flow (dscfm)	27497	27461	26726	27228
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)	0	0	0	0
Moisture (%)	15.8	15	14.9	15.2
Particulate Emissions				
g/dnm^3	0.1304	0.1236	0.1441	0.1327
Gr/dscf	0.057	0.054	0.063	0.058
ng/J	79.12	76.97	93.74	83.42
lb/10^6 Btu	0.184	0.179	0.218	0.194
Fuel Analysis				
Heating Value (kj/kg)	29896	29729	30487	30037
Heating Value (Btu/lb)	12,853	12,781	13,107	12,914
% Ash	8.4	11.5	8.0	8.0
% Sulfur	2.5	2.5	2.3	2.4
Average Opacity (%)				

Plant O

At Plant O two spreader stoker boilers each equipped with a single stage mechanical collector and Zurn Wet Scrubber were tested. The Zurn scrubber accomplishes combined SO_2/particulate removal. Boiler number 2 is rated at 80,000 pounds of steam per hour. Boiler number 3 has a rated capacity of 100,000 pounds of steam per hour. Sulfur oxide control is accomplished by maintaining the scrubber liquor at pH 12.

Three tests to determine the particulate collection efficiency were conducted on boiler number 2. Two tests were done on boiler number 3. All were in accordance with EPA Method 5. Boiler number 2 operated at 70,000 pounds of steam per hour during all three tests. Boiler number 3 operated at 100,000 pounds of steam per hour during the first test and at 80.000 pounds of steam per hour during the second test.[24]

PLANT O

Boiler #2

TEST SUMMARY SHEETS (Particulates Only) [24]

Test Number	One	Two	Three	Average
General Data				
Date	3/30/77	3/30/77	3/30/77	
Time				
Isokinetic Ratio (%)	96.5	97.3	97.1	97
Boiler Load (% of design)	88	88	88	88
Operating ΔP (inch H_2O)	12	12	12	12
Gas Data				
Velocity (mps)	13.32	12.77	13.69	13.26
Velocity (fps)	43.7	41.9	44.9	43.5
Flow (dnm^3/min)	807.12	775.97	832.61	805.22
Flow (dscfm)	28500	27400	29400	28433
Temperature (°C)	51.7	51.7	51.7	51.7
Temperature (°F)	125	125	125	125
Pressure (inches W.C.)				
Moisture (%)	14.5	14.1	14.2	14.3
Particulate Emissions				
g/dnm^3	0.1464	0.183	0.140	0.156
Gr/dscf	0.064	0.080	0.061	0.068
ng/J	58.05	99.33	88.58	82.0
lb/10^6 Btu	0.135	0.231	0.206	0.1907
Fuel Analysis				
Heating Value (kj/kg)	24165	24456	24195	24272
Heating Value (Btu/lb)	10389	10514	10402	10435
% Ash	9.64	10.09	9.88	9.87
% Sulfur	2.33	2.35	2.33	2.34
Average Opacity (%)				

PLANT O

Boiler #3

TEST SUMMARY SHEETS (Particulates Only)[24]

Test Number	One	Two	Three	Average
General Data				
Date	3/29/77	2/29/77		
Time				
Isokinetic Ratio (%)	95.0	97.4		96.2
Boiler Load (% of design)	100	80		90
Operating ΔP (inch H_2O)	12	12		12
Gas Data				
Velocity (mps)	10.97	10.46		10.72
Velocity (fps)	36.0	34.3		35.2
Flow (dnm^3/min)	886.4	815.6		815
Flow (dscfm)	31300	28800		30050
Temperature (°C)	54.4	54.4		54.4
Temperature (°F)	130	130		130
Pressure (inches W.C.)				
Moisture (%)	11.6	14.7		13.2
Particulate Emissions				
g/dnm^3	0.238	0.167		0.204
Gr/dscf	0.104	0.073		0.089
ng/J	119.97	86.86		103.63
lb/10^6 Btu	0.279	0.202		0.241
Fuel Analysis				
Heating Value (kj/kg)	24711	25167		24939
Heating Value (Btu/lb)	10624	10820		10722
% Ash	10.00	10.96		10.48
% Sulfur	2.21	2.45		2.33
Average Opacity (%)				

Plant II

Plant II has a 55,000 lb/hr of steam pulverized coal-fired boiler. Flue gas from this boiler (#2) is vented to a Joy Turbulaire scrubber. There is a multicyclone upstream of the scrubber. Tests were made at 95% of capacity and at a scrubber pressure drop of about 9 in. water. EPA test Method 5 was used to determine particulate emission. Opacity readings were taken in accordance with EPA Method 9.[25]

When comparing the boiler heat input rates calculated in the test report with values calculated by an alternative method, errors of 50% were noted. The calculated heat input rate directly affects the magnitude of the emission rate. Therefore, results from this emission test may not be representative of normal scrubber operation. As a result, the data is not presented with the support data for wet scrubbers.*

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* Memo and attachments from Phillips, W.R., Radian Corporation. July 3, 1980. Sorg Paper Company Wet Scrubber Tests - Middletown, Ohio Plant.

Plant II

TEST SUMMARY SHEETS (Particulates Only)[25]

Test Number	One	Two	Three*	Four
General Data				
Date	4/23/80	4/23/80	4/23/80	4/24/80
Time				
Isokinetic Ratio (%)	103.8	105.0	106.8	105.1
Boiler Load (% of design)				
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm³/min)	858	849	811	864
Flow (dscfm)	30290	29970	28631	30527
Temperature (°C)	44.2	49.2	49.7	39.4
Temperature (°F)	111.6	120.5	121.4	103.0
Pressure (inches W.C.)				
Moisture (%)	8.5	10.6	11.1	9.8
Particulate Emissions				
g/dnm³				
Gr/dscf	0.02736	0.06510	0.03989	0.01922
ng/J	28.29	67.51	46.87	20.60
lb/10⁶ Btu	0.0658	0.157	0.109	0.0479
Fuel Analysis				
Heating Value (kj/kg)	30578	32585	31138	30766
Heating Value (Btu/lb)	13,146	14,009	13,387	13,227
% Ash	9.94	6.36	7.52	9.48
% Sulfur	1.25	1.06	0.98	0.96
Average Opacity (%)	< 1	< 1	< 1	0

*Included a soot blowing cycle.

Plant LL

Plant LL has four coal-fired spreader stoker boilers. Particulate emissions were measured from Boilers #19, #20, and #22 which are each equipped with a mechanical collector and a venturi scrubber. The scrubbers are part of a dust alkali system designed to remove both PM and SO_2.

Process data for the tests on Boiler 22 are not well documented in the test report. In addition, plant personnel have suggested that the scrubber was not operated in a manner to provide optimum emission control during the tests.* Therefore, results of testing on Boiler 22 are not included with the support data for wet scrubbers.

There are two test reports for Boiler 19 at Plant LL. Early tests of this 236 x 10^6 Btu/hr heat input capacity stoker were supplied by the plant.[26] The Method 5 tests were conducted at a scrubber pressure drop of 18 inches of water. However, one test was conducted at low boiler load (55 percent). The low load test is not included in the wet scrubber support data, since low load conditions may not be fully representative of normal scrubber operation.

In August 1981, EPA also conducted emission tests at Plant LL.[27] The tests were run according to Method 5, but in order to evaluate the effect on sulfate and sulfuric acid formation on the measured emissions, EPA conducted simultaneous tests at two sample box temperatures. During each of the three runs, simultaneous tests were conducted, one at a sample box temperature of 120°C (248°F) and the other at a temperature of 160°C (320°F). Scrubber pressure drop averaged 19.3 inches of water.

During these summer tests the full output of the boiler was not required and some steam was exhausted to the atmosphere in order to a full load conditions. This phase of the test program was therefore limited to the three tests described above.

In December 1981, nine additional emission tests were conducted on Boiler 20.[28] Boiler 19 was out of service for scheduled maintenance outage. Boiler 20 is very similar to Boiler 19. These nine tests were a continuation of the test program started in August and described above. Before the tests, the venturi insert position on the scrubber of Boiler 20 had been adjusted to fully open and fixed in this position by welding the adjusting mechanism. The pressure drop across the scrubber varied with gas and liquor flow and was very steady, ranging from 17 to 18 inches of water.

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[*] Piccot, Steve. (Radian Corporation.) Telephone conversation with Plant LL personnel. May 1981.

PLANT LL

TEST SUMMARY SHEETS (Particulates Only)[26]

Test Number	Boiler 19	Boiler 19	Boiler 22	
General Data				
Date	6/13-15/79	6/13-15/79		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	100%	55%		
Operating ΔP (inch H_2O)	18.1	18.1		
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	51.2	44.7	135.5	
lb/10^6 Btu	0.119	0.104	0.315	
Fuel Analysis*				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash	10	10		
% Sulfur	2.4-3.4	2.4-3.4		
Average Opacity (%)				

**Average throughout testing at Plant LL.

PLANT LL

Boiler No. 19

Method 5 - Low Temperature

TEST SUMMARY SHEETS (Particulates Only)[27]

Test Number	One	Two	Three	Average
General Data				
Date	8/3/81	8/4/81	8/4/81	
Time	1:30-4:10	9:35-1:20	3:00-7:21	
Isokinetic Ratio (%)	104.6	98.7	99.0	100.8
Boiler Load (% of design)	71	75	75	73
Operating ΔP (inch H_2O)	18.5	19.6	20.0	19.3
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)	1100	1120	1160	1127
Flow (dscfm)	38700	39500	40900	39700
Temperature (°C)	57	59	59	58
Temperature (°F)	135	137	138	137
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.260	0.230	0.185	0.225
Gr/dscf	0.113	0.100	0.081	0.098
ng/J	134	114	85	111
$lb/10^6$ Btu	0.31	0.26	0.20	0.26
Fuel Analysis				
Heating Value (kj/kg)	24050	23300	24200	23850
Heating Value (Btu/lb)	10350	10000	10400	10250
% Ash	10.5	13.0	10.7	11.4
% Sulfur	2.65	2.6	2.6	2.62
Average Opacity (%)				

PLANT LL

Boiler No. 19

Method 5 - High Temperature

TEST SUMMARY SHEETS (Particulates Only)[27]

Test Number	One	Two	Three	Average
General Data				
Date	8/3/81	8/4/81	8/4/81	
Time	1:30-4:10	9:35-1:20	3:00-7:21	
Isokinetic Ratio (%)	104.9	96.5	103.0	101.5
Boiler Load (% of design)	71	75	75	73
Operating ΔP (inch H_2O)	18.5	19.6	20.0	19.3
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)	1100	1180	1170	1150
Flow (dscfm)	38900	41800	41300	40667
Temperature (°C)	57	59	59	58
Temperature (°F)	135	137	138	137
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.088	0.058	0.135	0.094
Gr/dscf	0.038	0.025	0.059	0.041
ng/J	45	29	62	45
lb/10^6 Btu	0.10	0.07	0.14	0.10
Fuel Analysis				
Heating Value (kj/kg)	24050	23300	24200	23850
Heating Value (Btu/lb)	10350	10000	10400	10250
% Ash	10.5	13.0	10.7	11.4
% Sulfur	2.65	2.6	2.6	2.62
Average Opacity (%)				

PLANT LL

Boiler No. 20

Method 5 - Low Temperature

TEST SUMMARY SHEETS (Particulates Only)[28]

Test Number	One	Two	Three	Four	Five
General Data					
Date	12/1/81	12/2/81	12/2/81	12/3/81	12/3/81
Time	1:52-4:05	8:20-10:20	1:20-3:17	7:40-9:30	11:00-12:48
Isokinetic Ratio (%)	98.9	96.9	103.6	102.2	100.4
Boiler Load (% of design)	87	87	85	87	90
Operating ΔP (inch H_2O)	17	18	18	17.75	17
Gas Data					
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)	1290	1370	1280	1330	1330
Flow (dscfm)	45600	48400	45100	46800	47000
Temperature (°C)	59	54	54	54	54
Temperature (°F)	139	129	129	129	129
Pressure (inches W.G.)					
Moisture (%)					
Particulate Emissions					
g/dnm^3	0.096	0.089	0.064	0.075	0.072
gr/dscf	0.042	0.043	0.028	0.033	0.031
ng/J	41.3	42.4	27.0	32.3	31.0
lb/10^6 Btu	0.10	0.10	0.06	0.08	0.07
Fuel Analysis					
Heating Value (kJ/kg)	24400	24510	25130	24420	25010
Heating Value (Btu/lb)	10500	10550	10820	10510	10760
% Ash	10.6	10.0	10.2	10.4	9.8
% Sulfur	2.5	2.8	2.2	2.5	2.5
Average Opacity (%)					

PLANT LL

Boiler No. 20

Method 5 - Low Temperature

TEST SUMMARY SHEETS (Particulates Only) [28]

Test Number	Six	Seven	Eight	Nine	Average
General Data					
Date	12/3/81	12/4/81	12/4/81	12/4/81	
Time	2:01-3:53	7:50-9:46	11:02-12:57	2:43-3:50	
Isokinetic Ratio (%)	100.0	100.9	97.3	99.7	100.0
Boiler Load (% of design)	91	90	90		88
Operating ΔP (inch H_2O)	17	17	17	17	17
Gas Data					
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)	1290	1350	1360	1380	1331
Flow (dscfm)	45600	47500	48100	48800	46989
Temperature (°C)	54	53	53	54	54
Temperature (°F)	129	128	128	130	130
Pressure (inches W.G.)					
Moisture (%)					
Particulate Emissions					
g/dnm^3	0.062	0.069	0.081	0.096	0.079
gr/dscf	0.027	0.030	0.036	0.042	0.035
ng/J	26.9	29.8	35.7	41.4	34.2
$lb/10^6$ Btu	0.06	0.07	0.08	0.10	0.08
Fuel Analysis					
Heating Value (kJ/kg)	24660	25360	24120	24760	24708
Heating Value (Btu/lb)	10610	10920	10380	10660	10634
% Ash	10.3	10.3	11.8	10.0	10.4
% Sulfur	2.3	2.2	3.1	2.8	2.54
Average Opacity (%)					

PLANT LL

Boiler No. 20

Method 5 - High Temperature

TEST SUMMARY SHEETS (Particulates Only)[28]

Test Number	One	Two	Three	Four	Five
General Data					
Date	12/1/81	12/2/81	12/2/81	12/3/81	12/3/81
Time	1:52-4:05	8:20-10:20	1:20-3:17	7:40-9:30	11:00-12:48
Isokinetic Ratio (%)	102.0	101.0	100.4	100.2	99.2
Boiler Load (% of design)	87	87	85	87	90
Operating ΔP (inch H_2O)	17	18	18	17.75	17
Gas Data					
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)	1290	1350	1300	1340	1340
Flow (dscfm)	45700	47500	45800	47200	47300
Temperature (°C)	59	54	54	54	54
Temperature (°F)	139	129	129	129	129
Pressure (inches W.G.)					
Moisture (%)					
Particulate Emissions					
g/dnm^3	0.108	0.092	0.078	0.070	0.066
gr/dscf	0.047	0.040	0.034	0.030	0.029
ng/J	46.6	39.8	33.0	29.9	28.3
$lb/10^6$ Btu	0.11	0.09	0.08	0.07	0.08
Fuel Analysis					
Heating Value (kJ/kg)	24400	24510	25130	24420	25010
Heating Value (Btu/lb)	10500	10550	10820	10510	10760
% Ash	10.6	10.0	10.2	10.4	9.8
% Sulfur	2.5	2.8	2.2	2.5	2.5
Average Opacity (%)					

PLANT LL
Boiler No. 20
Method 5 - High Temperature

TEST SUMMARY SHEETS (Particulates Only)[28]

Test Number	Six	Seven	Eight	Nine	Average
General Data					
Date	12/3/81	12/4/81	12/4/81	12/4/81	
Time	2:01-3:53	7:50-9:46	11:02-12:57	2:43-3:50	
Isokinetic Ratio (%)	102.9	96.7	99.1	101.0	100.3
Boiler Load (% of design)	91	90	90		88
Operating ΔP (inch H_2O)	17	17	17	17	17
Gas Data					
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)	1260	1370	1380	1390	1336
Flow (dscfm)	44600	48300	48800	48900	47122
Temperature (°C)	54	53	53	54	54
Temperature (°F)	129	128	128	130	130
Pressure (inches W.G.)					
Moisture (%)					
Particulate Emissions					
g/dnm^3	0.060	0.069	0.081	0.096	0.080
gr/dscf	0.026	0.030	0.025	0.029	0.032
ng/J	25.7	29.7	25.1	28.9	31.9
lb/10^6 Btu	0.06	0.07	0.06	0.07	0.07
Fuel Analysis					
Heating Value (kJ/kg)	24660	25360	24120	24760	24708
Heating Value (Btu/lb)	10610	10920	10380	10660	10634
% Ash	10.3	10.3	11.8	10.0	10.4
% Sulfur	2.3	2.2	3.1	2.8	2.54
Average Opacity (%)					

Plant MM

Plant MM contains five spreader stoker boilers equipped with mechanical collectors and Venturi dual alkali scrubbers for combined SO_2/PM removal. Fly ash from the mechanical collector hoppers is reinjected into the boiler. Boilers #2 and #3 have identical 295 million Btu/hr ratings. Design pressure drop across the scrubbers is approximately 17 inches of water.

All tests were run using EPA Method 5. Both boilers were tested at 75 percent load, with fly ash reinjection during both tests.[26]

PLANT MM

TEST SUMMARY SHEETS (Particulates Only)[26]

Test Number	One	Two	Three	Average
General Data	Boiler #2	Boiler #3		
Date	6/5/79	6/6/79		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	75%	75%		
Operating P (Inch H_2O)	16	17.5		
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	68.8	76.5		
lb/10^6 Btu	0.160	0.178		
Fuel Analysis *				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				10
% Sulfur				2.4-3.4
Average Opacity (%)				

*Fuel analysis is for a representative coal burned at Plant MM.

Plant NN

Plant NN contains two spreader stoker boilers equipped with mechanical collectors and Zurn entrainment type dual alkali scrubbers. Both boilers are rated at 71 million Btu/hr. Pressure drop during the tests is approximately eight inches of water.

All test runs were made using EPA Method 5. Boiler #2 was tested at 100 percent load, and then tested at 50 percent load. Fly ash was being reinjected during both tests.[26] Scrubber pressure drop during the tests were not presented in the test report. For this reason the scrubber operation cannot be fully characterized. Therefore, the data from Plant NN are not included with the support data for wet scrubbers.

PLANT NN

TEST SUMMARY SHEETS (Particulates Only)[26]

Boiler #2

Test Number	One *	Two *	Three	Average
General Data				
Date				
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	100	50		
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	64.5	61.49		
lb/10^6 Btu	0.150	0.143		
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)				

*Fly ash reinjection both tests.

Plant OO

Plant OO consists of two 40 MW (136.5 x 10^6 Btu/hr) pulverized, dry bottom boilers retrofitted with three 20 MW prototype flue gas desulfurization units. One of these units is a concentrated dual alkali scrubber supplied by Combustion Equipment Associates/Arthur D. Hill. The scrubber consists of a venturi followed by a sieve tray tower. Three series of tests were conducted using EPA Method 5 to evaluate particulate removal efficiency. One series of tests was made with the upstream electrostatic precipitator fully charged, (Tests 2 - 4). A second series was made with half the precipitator out of service (Tests 5 - 7). All tests where the ESP was in service are not included in the support data for wet scrubbers.

A third series of tests was conducted with the precipitator turned off (Tests 8 - 13). Results from this series are averaged and presented as support data for wet scrubber performance. In all three test series, venturi pressure drop was compared at 12 inches w.g. and 17 inches w.g. for effects upon outlet emissions. Tests are averaged separately depending on the pressure drop used during testing. Boiler load averaged 95 percent.[29]

PLANT OO

Low Pressure Drop Tests

TEST SUMMARY SHEETS (Particulates Only)[29]

Test Number	One	Two	Three	Average
General Data				
Date	6/15/76 - 7/1/76			
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)				
Venturi ΔP (inch H_2O)	12	12	12	12
Sieve Tray ΔP (inch H_2O)	4.5	4.5	4.5	4.5
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.85	0.055	0.078	0.328
Gr/dscf	0.037	0.024	0.034	0.032
ng/J	32.2	21.1	29.7	27.7
lb/10^6 Btu	0.075	0.049	0.069	0.064
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)				

PLANT OO

TEST SUMMARY SHEETS (Particulates Only) [29]

Test Number	One[a]	Two[a]	Three[a]	Four[b]
General Data				
Date		6/15 to 7/1/76		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)				
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm³/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm³	0.027	0.034	0.025	0.059
Gr/dscf	0.012	0.015	0.011	0.026
ng/J	10.3	12.9	9.46	22.8
lb/10⁶ Btu	0.024	0.030	0.022	0.053
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)		12200		
% Ash		12.3		
% Sulfur		3.5		
Average Opacity (%)				

a) ESP at full operating capacity
b) ESP at half operating capacity

PLANT OO

TEST SUMMARY SHEETS (Particulates Only)[29]

Test Number	Five [a]	Six [a]		
General Data				
Date		6/15/76-7/1/76		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)				
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.048	0.062		
Gr/dscf	0.021	0.027		
ng/J	18.5	23.6		
lb/10^6 Btu	0.043	0.055		
Fuel Analysis		AVERAGE		
Heating Value (kj/kg)				
Heating Value (Btu/lb)		12.3		
% Ash		3.5		
% Sulfur				
Average Opacity (%)				

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[a] ESP at half operating capacity

PLANT 00
High Pressure Drop Tests
TEST SUMMARY SHEETS (Particulates Only)[29]

Test Number	One	Two	Three	Average
General Data				
Date		6/15/76 - 7/1/76		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)				
Venturi ΔP (inch H_2O)	17	17	17	17
Sieve Tray ΔP (inch H_2O)	4.5	4.5	4.5	4.5
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.085	0.076	0.080	0.080
Gr/dscf	0.037	0.033	0.035	0.035
ng/J	32.2	28.8	30.5	30.5
$lb/10^6$ Btu	0.075	0.067	0.071	0.071
Fuel Analysis		AVERAGE		
Heating Value (kj/kg)		12200		
Heating Value (Btu/lb)		12.3		
% Ash		3.5		
% Sulfur				
Average Opacity (%)				

PLANT QQ

Boilers No. 4 and No. 5 at Plant QQ are both spreader stokers. Both use a mechanical collector and venturi dual alkali scrubber for combined SO_2/PM removal. The boilers are each rated at 202 x 10^6 Btu/hr heat input. Load was varied during the EPA-5 tests as shown on the following table. The pressure drop through the scrubber was about eight inches of water during all tests.[26]

Low load tests conducted on boilers 4 (65%) and 5 (50%) may not be representative of normal scrubber opperation. Therefore, these tests are not included in the support data for wet scrubbers. The average of tests conducted on boilers 4 and 5 do not include these low load tests.

Fly ash from the mechanical collector hoppers was reinjected into both boilers 4 and 5. However, one test on boiler 5 (Test 2) was conducted without the use of fly ash reinjection. This test is presented separately from the other boiler 5 tests, and is not included in the average of tests presented on the Summary Sheet.

PLANT QQ

TEST SUMMARY SHEETS (Particulates Only)[26]

Boiler #4

Test Number	One	Two	Three	Average*
General Data				
Date	4/23-27/79	4/23-27/79	2/23-27/79	
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	90-100	80	65	88
Operating ΔP (inch H_2O)				8
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	71.81	60.2	43.0	66.0
$lb/10^6$ Btu	0.167	0.140	0.100	0.154
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				10
% Sulfur				2.4-3.4
Average Opacity (%)				

* Tests One and Two only. Test Three not included because of low load.

PLANT QQ

TEST SUMMARY SHEETS (Particulates Only)[26]

Boiler #5

Test Number	One	Two **	Three	Four	Five	Average*
General Data						
Date	6/26-29/79	6/26-29/79	6/26-29/79	6/26-29/79		
Time						
Isokinetic Ratio (%)						
Boiler Load (% of rating)	95	95	80	80	50	80
Operating ΔP (inch H_2O)						8
Gas Data						
Velocity (mps)						
Velocity (fps)						
Flow (dnm^3/min)						
Flow (dscfm)						
Temperature (°C)						
Temperature (°F)						
Pressure (inches W.G.)						
Moisture (%)						
Particulate Emissions						
g/dnm^3						
gr/dscf						
ng/J	113.9	103.2	68.8	60.2	41.28	80.97
lb/10^6 Btu	0.265	0.24	0.16	0.14	0.096	0.19
Fuel Analysis ***						
Heating Value (kJ/kg)						
Heating Value (Btu/lb)						
% Ash						10
% Sulfur						2.4-3.4
Average Opacity (%)						

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* Test 5 not included in average because of low load. Test 2 not included because fly ash reinjection was not used.

** Fly ash reinjection not used during this run.

*** Fuel analysis is for a representative coal burned at Plant QQ.

PLANT SS

Plant SS contains four spreader stoker boilers each equipped with a mechanical dust collector and a multiventuri flex tray double alkali scrubber. Particulate emission tests were conducted on boiler number 3 which has a rated capacity of 60,000 pounds of steam per hour. Boiler load ranged from 71 to 81 percent of capacity during testing. Neither boiler nor scrubber was operating in a stable manner. Boiler load fluctuated between 40,000 and 52,000 pounds of steam per hour.

The two low load tests (<75%) run on boiler number three are not included in the support data for wet scrubbers. These data are not included because operation under low load conditions may not be representative of normal scrubber operation.

It should be noted that the testing contractor felt that the scrubber was not operating representatively. The outlet scrubber liquor pH varied from 3.6 to 7.6 because of problems with the lime feed system. This may have affected the measured particulate emissions.[30]

PLANT SS

TEST SUMMARY SHEETS (Particulates Only)[30]

Test Number	One	Two	Three	Average
General Data				
Date	12/20/79	12/20/79	12/20/79	
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	81	73	71	
Operating AP (inch H_2O)				7.5
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)	21808	21214	21584	
Temperature (°C)	59	60	57	
Temperature (°F)	139	140	134	
Pressure (inches W.C.)				
Moisture (%)	15	14	14	
Particulate Emissions				
g/dnm^3	0.098	0.08	0.094	
Gr/dscf	0.043	0.035	0.041	
ng/J	68.8	60.2	81.7	
lb/10^6 Btu	0.16	0.14	0.19	
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				5
% Sulfur				2.14
Average Opacity (%)				

PLANT TT

A pulverized coal boiler with a rated capacity of 100 x 10^6 Btu/hr was tested at Plant TT. It is equipped with a venturi/spray tower FGD scrubber system using a lime slurry scrubbing solution. Ten particulate tests were performed to determine the effect of major operating variables. These variables included MgO addition, venturi pressure drop, gas rate, slurry rate, mist eliminator configuration, and percent solids recirculated. All tests were conducted in accordance with EPA Method 5.

Tests 2 and 3 were performed on a ESP treated gas stream. These tests are not included in the support data for wet scrubbers. In addition, test 5 was not included in the support data for wet scrubbers because of low load conditions. Operation at low load may yield results that may not be representative of normal scrubber operation.

The tests are arranged according to the scrubber operating pressure drop. Normal pressure drop tests (5-9 inches H_2O) are grouped and averaged together. The one low pressure drop test (3 inch H_2O) is not included in this averaging and is presented separately.

PLANT TT

Normal Pressure Drop Tests
TEST SUMMARY SHEETS (Particulates Only)[31]

Test Number	One	Two*	Three*	Four
General Data				
Date	10/10/76	10/20/76	10/20/76	10/29/76
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	100	100	100	100
Operating ΔP (inch H_2O)	9	9	9	9
Gas Data				
Velocity (mps)				
Velocity (fps)	9.4	9.4	9.4	9.4
Flow (dnm^3/min)	53520	53520	53520	53520
Flow (dscfm)	23388	23388	23388	23388
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.073	0.114	0.012	0.044
Gr/dscf	0.032	0.005	0.005	0.019
ng/J	26.2	5.16	5.16	16.8
$lb/10^6$ Btu	0.061	0.012	0.012	0.039
Fuel Analysis	AVERAGE FOR ALL TESTS			
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash		14.7		
% Sulfur		3.9		
Average Opacity (%)				

* ESP was in service during these two tests.

PLANT TT

Normal Pressure Drop Tests

TEST SUMMARY SHEETS (Particulates Only)[31]

Test Number	Five	Six	Seven	Eight
General Data				
Date	11/2/76	11/6/76	11/10/76	11/18/76
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	57	100	100	100
Operating ΔP (inch H_2O)	9	5.3	9	9
Gas Data				
Velocity (mps)				
Velocity (fps)	5.4	9.4	9.4	9.4
Flow (dnm^3/min)	30582	53520	53520	53520
Flow (dscfm)	13364	23388	23388	23388
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.60	0.064	0.062	0.048
Gr/dscf	0.026	0.028	0.027	0.021
ng/J	21.1	24.1	22.8	17.2
$lb/10^6$ Btu	0.049	0.056	0.053	0.040
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)				

PLANT TT

Normal Pressure Drop Tests

TEST SUMMARY SHEETS (Particulates Only) 31

Test Number	Nine			Average*
General Data				
Date	11/22/76			
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	100			100
Operating ΔP (inch H_2O)	9			8.4
Gas Data				
Velocity (mps)				
Velocity (fps)	9.4			9.4
Flow (dnm^3/min)	53520			53520
Flow (dscfm)	23388			23388
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.060			0.059
Gr/dscf	0.026			0.037
ng/J	20.6			21.25
$lb/10^6$ Btu	0.048			0.049
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)				

* Average does not include tests 2 and 3 where an ESP was used. Also does not include Test 5 which was conducted at an average 57% load.

PLANT TT

Low Pressure Drop Test

TEST SUMMARY SHEETS (Particulates Only)[31]

Test Number		One		
General Data				
Date		11/27/76		
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)		100		
Operating ΔP (inch H_2O)		3		
Gas Data				
Velocity (mps)				
Velocity (fps)		9.4		
Flow (dnm^3/min)		53520		
Flow (dscfm)		23388		
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3		0.082		
Gr/dscf		0.036		
ng/J		31.0		
lb/10^6 Btu		0.072		
Fuel Analysis				
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash		14.7		
% Sulfur		3.9		
Average Opacity (%)				

Plant AAA

Emissions from boiler no. 1 at Plant AAA were tested by EPA to determine the quantity of emissions and the effectiveness of the control device. The spreader stoker boiler tested has a steam capacity of 100,000 lb/hr firing waste oil and coal. Waste oil was not fired during the testing period. It is equipped with an economizer, multiclone and double alkali scrubber. The scrubber has four, three-stage multiventuri flexi-tray scrubber modeules with a pressure drop of 19 cm H_2O (7.5 in. H_2O). The design flow if 65,500 acfm at 80°F (30.9 m^3/s at 27°C).

Testing was performed using simultaneous EPA Method 5 at different sample box temperatures. In one sample train the filter and probe temperature was maintained at 177°C (350°F) to avoid collection of condensed SO_3. The other sample train was maintained at the more common Method 5 temperature of 120°C (248°F). Three simultaneous tests were run with the boiler operating at about 92 percent capacity.[32]

Plant AAA

Method 5*

TEST SUMMARY SHEETS (Particulates Only)[32]

Test Number	One	Two	Three	Average
General Data				
Date	11/13/80	11/13/80	11/14/80	
Time				
Isokinetic Ratio (%)	103.0	101.3	99.4	101.2
Boiler Load (% of design)	92	92	92	92
Operating ΔP(inch H_2O)	7.5	7.5	7.5	7.5
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)	813	815	789	806
Flow (dscfm)	28696	28780	27843	28440
Temperature (°C)	47	47	47	47
Temperature (°F)	117	117	116	117
Pressure (inches W.C.)	7.9	7.9	7.3	7.7
Moisture (%)	11.68	14.31	12.04	12.68
Particulate Emissions				
g/dnm^3	0.0968	0.1154	0.1016	0.1046
Gr/dscf	0.0423	0.0504	0.0444	0.0457
ng/J	48.9	57.8	49.6	52.1
lb/10^6 Btu	0.114	0.134	0.115	0.121
Fuel Analysis				
Heating Value (kj/kg)	32872	32965	32979	32939
Heating Value (Btu/lb)	14142	14182	14188	14171
% Ash	5.13	4.43	3.51	4.36
% Sulfur	1.09	1.48	1.43	1.33
Average Opacity (%)				

*Sample box temperature (filter and probe) = 120°C (248°F).

Plant AAA

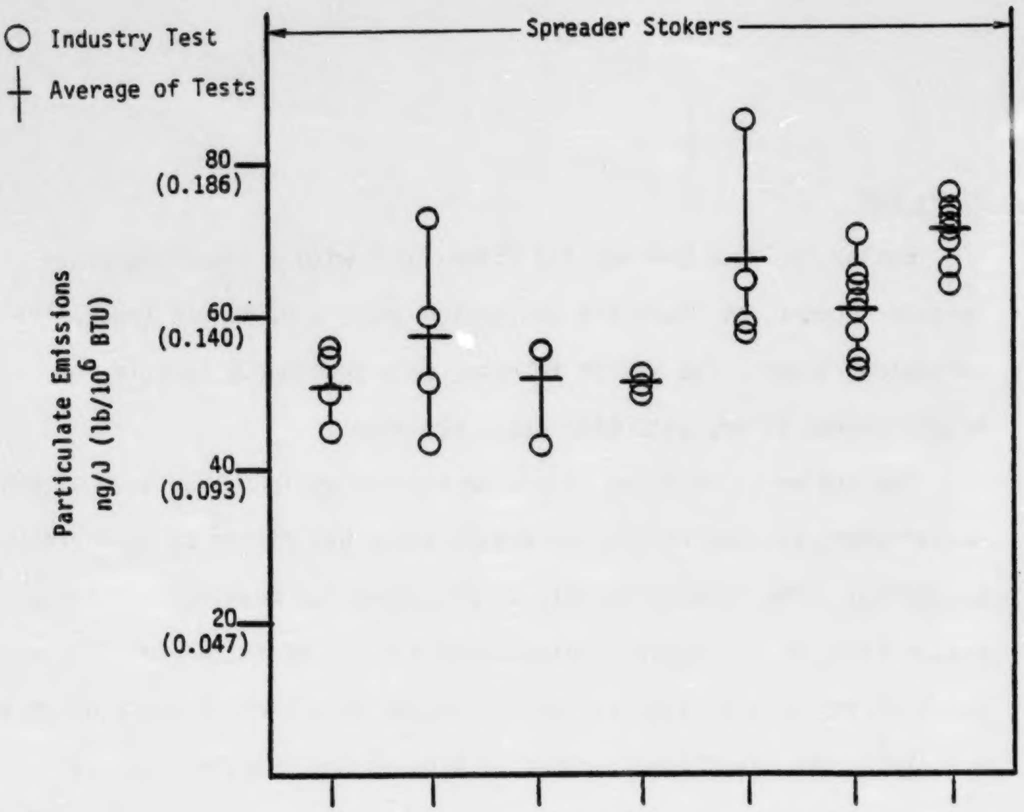
Method 5*

TEST SUMMARY SHEETS (Particulates Only) [32]

Test Number	One	Two	Three	Average
General Data				
Date	11/13/80	11/13/80	11/14/80	
Time				
Isokinetic Ratio (%)	99.2	98.4	100.1	99.2
Boiler Load (% of design)	92	92	92	92
Operating ΔP (inch H_2O)	7.5	7.5	7.5	7.5
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)	827	834	792	818
Flow (dscfm)	29185	29438	27953	28859
Temperature (°C)	48	48	47	48
Temperature (°F)	118	118	117	118
Pressure (inches W.C.)	7.9	7.9	7.3	7.7
Moisture (%)	11.69	13.08	12.56	12.44
Particulate Emissions				
g/dnm^3	0.0489	0.0976	0.0598	0.0688
Gr/dscf	0.0213	0.0426	0.0261	0.030
ng/J	23.8	48.5	31.1	34.5
lb/10^6 Btu	0.055	0.113	0.072	0.080
Fuel Analysis				
Heating Value (kj/kg)	32872	32965	32979	32939
Heating Value (Btu/lb)	14142	14182	14188	14171
% Ash	5.13	4.43	3.51	4.36
% Sulfur	1.09	1.48	1.43	1.33
Average Opacity (%)				

*High sample box temperature [177°C (350°F)].

C.1.6 PARTICULATE EMISSION DATA FOR SIDE STREAM SEPARATORS



Plant	DDD	CCC	GGG	EEE	FFF	EEE	BBB
Boiler Number	-	-	-	1	3	3	3
Design Capacity (10^3 lb steam/hr)	45	70	60	40	100	55	52
Operating Capacity (% of Design)	68[b]	71-80	74-80	84-93	85-97	99-105	97-108
Average Opacity (%)	0[c]	-	-	6.9	0	0[c]	6[c]
Fuel Sulfur (Wt %)	0.82	0.80	0.94	1.79	1.67	2.09	0.80
Fuel Ash (Wt %)	9.7	10.1	4.3	9.0	6.1	8.8	7.8
% of Flow to Baghouse	16[b]	31	30	37	15	15	17

Figure C.1.6-1. Side stream separator emission data.[a]

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[a] All tests ordered from left to right by increasing operating capacity

[b] Data presented are averages for all tests

Plant BBB

Boiler no. 3, a Babcock and Wilcox unit with a traveling grate spreader stoker, at Plant BBB was tested under a U. S. EPA Innovative Technology Order. The boiler is rated at a continuous capacity of 52,000 pounds of dry saturated steam per hour.

The boiler is equipped with a mechanical cyclone (Joy 9 VM with a design pressure drop of 3.8 in. W.G.), and a bag filter (a Pulse Flow FP SQ4508). The filter consists of a rectangular housing containing 144 filter bags, 4 1/2 inches in diamter by 8 ft. The filter provides a total filter area of 1395 ft^2 with a design air-to-cloth ratio of 6.45 $scfm/ft^2$. The bag filter receives a side stream which represents between 16 to 18 percent of the boiler exhaust after it has passed through the cyclone. The side stream is taken from the base of the cyclone.

Eight particulate emission tests were taken using EPA Method 5. During the first four tests the bag filter received 18 percent of the total boiler exhaust flow and 16 percent during the last four tests. Boiler load averaged 103 percent.[33] Opacity was determined with a Bailey smoke density recorder.

PLANT BBB

TEST SUMMARY SHEETS (Particulates Only)[33]

Test Number	One	Two	Three	Four
General Data				
Date	3/31/80	4/1/80	4/1/80	4/1/80
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	106	106	105	97
Percent flow to baghouse	16	16	16	16
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)				
Flow (dscfm)				
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	64.9	75.2	71.4	73.5
lb/10^6 Btu	0.151	0.175	0.166	0.171
Fuel Analysis	Average for Tests 1-4			
Heating Value (kj/kg)				
Heating Value (Btu/lb)				
% Ash				
% Sulfur				
Average Opacity (%)	6	6	6	6

PLANT BBB

TEST SUMMARY SHEETS (Particulates Only)[33]

Test Number	Five	Six	Seven	Eight	Average
General Data					
Date	4/2/80	4/2/80	4/2/80	4/2/80	
Time					
Isokinetic Ratio (%)					
Boiler Load (% of rating)	101	98	108	104	103
Percent flow to baghouse*	18	18	18	18	17
Gas Data					
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)					
Flow (dscfm)					
Temperature (°C)					
Temperature (°F)					
Pressure (inches W.G.)					
Moisture (%)					
Particulate Emissions					
g/dnm^3					
gr/dscf					
ng/J	74.4	66.2	71.8	70.5	71.0
lb/10^6 Btu	0.173	0.154	0.167	0.164	0.165
Fuel Analysis		Average for Tests 5-8			
Heating Value (kJ/kg)		30529			30420
Heating Value (Btu/lb)		13125			13078
% Ash		7.65			7.8
% Sulfur		0.81			0.80
Average Opacity (%)	6	6	6	6	6

Plant CCC

Plant CCC's boiler No. 3 is a Riley boiler with a traveling grate spreader stoker rated at a continuous capacity of 70,000 lb/hr of dry saturated steam.

The boiler is equipped with a mechanical cyclone, a Joy 9 VM with a design pressure drop of 2.95 inches W.G., and a bag filter, a pulse flow PF SQ4508. The filter has a rectangular housing containing 144 filter bags, each 4 1/2 inches in diameter by 8 ft. The filter provides a total filter area of 1395 ft.^{2} with a design air-to-cloth ratio of 6.45 scfm/ft^2. The bag filter receives approximately 15 percent of the boiler exhaust after it has passed through the cyclone. The gas stream going to the bag filter is taken at the base of the cyclone.

The particulate collection system was tested under a U. S. EPA Innovative Technology Order. Four tests were conducted using EPA Method 5. During testing approximately 31 percent of the total boiler exhaust flow was sent to the bag filter. Boiler load averaged 76 percent.[33]

PLANT CCC

TEST SUMMARY SHEETS (Particulates Only)[33]

Test Number	One	Two	Three	Four	Average
General Data					
Date	February 26 and 27, 1980				
Time					
Isokinetic Ratio (%)					
Boiler Load (% of rating)	71	80	77	77	76
Percent flow to baghouse*	31	31	31	31	31
Gas Data					
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)	610	560	535	580	571
Flow (dscfm)	21530	19780	18880	20470	20165
Temperature (°C)					
Temperature (°F)					
Pressure (inches W.G.)					
Moisture (%)					
Particulate Emissions					
g/dnm^3					
gr/dscf					
ng/J	73.1	60.2	43.0	51.6	56.98
lb/10^6 Btu	0.17	0.14	0.10	0.12	0.13
Fuel Analysis					
Heating Value (kJ/kg)					26556
Heating Value (Btu/lb)					11417
% Ash					10.13
% Sulfur					0.80
Average Opacity (%)					

* Average for all tests

Plant DDD

Boiler no. 1 is a Babcock and Wilcox unit with a traveling grate spreader stoker. The capacity is 45,000 lbs/hr of steam.

The particulate collection equipment consists of a Joy 9 VM series mechanical cyclone with a 3.5 inch W.G. pressure drop and a Pulse Jet PF SQ4508 bag filter. The bag filter has a rectangular housing containing 144, 4 1/2 inch diameter by 8 ft., filter bags. The filter has a total filter area of 1395 ft^2 with a design air-to-cloth ratio of 6.45 $scfm/ft^2$. The filter receives approximately 15 percent of the boiler exhaust after it has passed through the mechanical cyclone. The gas to the filter is taken at the base of the cyclone.

Four tests were conducted using EPA Method 5 under a U. S. EPA Innovative Technology Order. During testing approximately 16 percent of the total boiler exhaust flow was sent to the filter. The boiler load averaged 68 percent.[33]

PLANT DDD

TEST SUMMARY SHEETS (Particulates Only)[33]

Test Number	One	Two	Three	Four	Average
General Data					
Date	4/15/80	4/15/80	4/16/80	4/16/80	
Time					
Isokinetic Ratio (%)					
Boiler Load (% of rating)*	68	68	68	68	68
Percent flow to baghouse*	16	16	16	16	16
Gas Data					
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)	435	389	425	483	433
Flow (dscfm)	15350	13731	15001	17040	15281
Temperature (°C)					
Temperature (°F)					
Pressure (inches W.G.)					
Moisture (%)					
Particulate Emissions					
g/dnm^3					
gr/dscf					
ng/J	55.9	55.0	49.9	44.7	51.4
lb/10^6 Btu	0.130	0.128	0.116	0.104	0.120
Fuel Analysis					
Heating Value (kJ/kg)					30084
Heating Value (Btu/lb)					12934
% Ash					9.74
% Sulfur					0.82
Average Opacity (%)	0	0	0	0	0

* Average for all tests. Test specific data was not recorded.

Plant EEE

Two boilers, boilers 1 and 3, were tested at Plant EEE under a U. S. EPA Innovative Technology Order. Boiler 1 is a Babcock and Wilcox unit with a traveling grate spreader stoker rated at 40,000 lb/hr of dry saturated steam. Boiler 3 is also a Babcock and Wilcox unit with a traveling grate spreader stoker rated at 55,000 lb/hr of dry saturated steam.

Both boilers are equipped with a mechanical cyclone and bag filter particulate control system. The filter receives only a portion (approximately 15 percent) of the exhaust gas after it has passed through the cyclone. The mechanical cyclone on boiler no. 1 is a Joy 9 VGA-107 with a 3.8 inch W.G. pressure drop and boiler no. 3 also has a Joy 9 VG-107 with a 3.8 inch W.G. pressure drop. Both boilers have a pulse flow PF SQ4508 fabric filter with 144, 4 1/2 inch diameter by 8 ft., filter bags. The filter has a total filter area of 1395 ft^2 with a design air-to-cloth ratio of 6.45 $scfm/ft^2$.

Eight particulate emission tests were conducted on boiler no. 3 and three tests on boiler no. 1 using EPA Method 5. During testing approximately 37 percent of the boiler no. 1's exhaust gas flow was sent to the filter and 15 percent of the boiler no. 3's exhaust gas flow was sent to its filter. The boiler load averaged 89 percent and 93 percent for boiler no. 1 and 3 respectively.[33]

PLANT EEE
BOILER NO. 1
TEST SUMMARY SHEETS (Particulates Only)

33

Test Number	One	Two	Three	Average
General Data				
Date	2/6/80	2/6/80	2/6/80	
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)	93	84	91	89
Percent flow to baghouse*	37	37	37	37
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)	362	363	373	366
Flow (dscfm)	12789	12826	13159	12925
Temperature (°C)				
Temperature (°F)				
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3				
Gr/dscf				
ng/J	52.8	51.6	50.3	51.7
lb/10^6 Btu	0.123	0.120	0.117	0.12
Fuel Analysis				
Heating Value (kj/kg)				28842
Heating Value (Btu/lb)				12400
% Ash				8.99
% Sulfur				1.79
Average Opacity (%)	10	5	5	6.9

*** Average for all tests.**

PLANT EEE
BOILER NO. 3

TEST SUMMARY SHEETS (Particulates Only)[33]

Test Number	One	Two	Three	Four
General Data				
Date	3/24/80	3/25/80	3/25/80	3/25/80
Time				
Isokinetic Ratio (%)				
Boiler Load (% of design)[a]	101	99	103	100
Percent flow to baghouse	15	15	15	15
Gas Data				
Velocity (mps)				
Velocity (fps)				
Flow (dnm^3/min)	596	590	583	601
Flow (dscfm)	21046	20851	20578	21224
Temperature (°C)	177	166	167	170
Temperature (°F)	350	331	333	338
Pressure (inches W.C.)				
Moisture (%)				
Particulate Emissions				
g/dnm^3	0.119	0.104	0.112	0.120
Gr/dscf	0.0518	0.0453	0.0491	0.0523
ng/J	61.5	52.9	54.2	58.5
lb/10^6 Btu	0.143	0.123	0.126	0.136
Fuel Analysis	Average for Tests 1-4			
Heating Value (kj/kg)		29415		
Heating Value (Btu/lb)		12646		
% Ash		8.76		
% Sulfur		2.09		
Average Opacity (%)[b]	0	0	0	0

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[a] Average during testing.

[b] Opacity was determined by Bailey Smoke Density recorder.

PLANT EEE
BOILER NO. 3
TEST SUMMARY SHEETS (Particulates Only)[33]

Test Number	Five	Six	Seven	Eight	Average
General Data					
Date	3/26/80	3/26/80	3/26/80	3/26/80	
Time					
Isokinetic Ratio (%)					
Boiler Load (% of rating)[a]	105	104	102	100	102
Percent flow to baghouse	15	15	15	15	15
Gas Data					
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)	596	592	589	596	593
Temperature (°C)	21039	20913	20801	21039	20936
Temperature (°F)	170	172	177	175	172
Pressure (inches W.G.)	338	341	350	347	341
Moisture (%)					
Particulate Emissions					
g/dnm^3	0.133	0.126	0.132	0.142	0.124
gr/dscf	0.0583	0.0551	0.0577	0.0621	0.0540
ng/J	64.1	61.9	65.8	70.9	61.2
lb/10^6 Btu	0.149	0.144	0.153	0.165	0.142
Fuel Analysis	Average for Tests 5 - 8				
Heating Value (kJ/kg)		28291			28853
Heating Value (Btu/lb)		12163			12405
% Ash		8.76			8.76
% Sulfur		2.09			2.09
Average Opacity (%)[b]	0	0	0	0	

---

[a] Average during testing.

[b] Opacity was determined by Bailey Smoke Density recorder.

Plant FFF

Boiler No. 3, a Babcock and Wilcox traveling grate spreader stoker, with a capacity of 100,000 lb/hr of dry saturated steam was tested under a U. S. EPA Innovative Technology Order.

The particulate control system consists of a Universal Oil BT-6-UPE-WHT mechanical cyclone with a design pressure drop of 11 inches W.G. and a Standard Havens Beta Mark III bag filter containing 156, 6 1/2 inch diameter by 14 ft., filter bags. The filter thus provides a total filter area of 3259 $ft.^2$ and has a design air-to-cloth ratio of 3.44 $scfm/ft^2$. The bag filter receives only a portion of the total boiler exhaust. Approximately 15 percent of the gas flow is ducted from the base of the cyclone to the bag filter.

Four particulate emission tests were conducted using EPA Method 5. During testing 17 percent of the total boiler gas flow was sent to the filter. Boiler load averaged 89 percent.[33]

PLANT FFF

TEST SUMMARY SHEETS (Particulates Only)[33]

Test Number	One	Two	Three	Four	Average
General Data					
Date	January 8-9, 1980				
Time					
Isokinetic Ratio (%)					
Boiler Load (% of rating)	86	85	87	97	89
Percent flow to baghouse*	15	15	15	15	15
Gas Data					
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)	965	958	944	961	954
Flow (dscfm)	33704	33830	33322	33942	33700
Temperature (°C)					
Temperature (°F)					
Pressure (inches W.G.)					
Moisture (%)					
Particulate Emissions					
g/dnm^3					
gr/dscf					
ng/J	86.0	65.8	58.5	57.6	67.0
$lb/10^6$ Btu	0.200	0.153	0.136	0.134	0.156
Fuel Analysis[a]					
Heating Value (kJ/kg)					30503
Heating Value (Btu/lb)					13114
% Ash					6.11
% Sulfur					1.67
Average Opacity (%)[b]					<1

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[a] Average for all tests.

[b] One-hour opacity evaluation.

Plant GGG

Boiler No. 3, a Babcock and Wilcox unit with a traveling grate spreader stoker, was tested under a U. S. EPA Innovative Technology order. The boiler is rated at 60,000 lb/hr of dry saturated steam.

The particulate control system consists of a mechanical cyclone and a bag filter. The mechanical cyclone is a Western Precipitation 9 VG12 with a 2.5 inch pressure drop. The bag filter receives only a portion of the total boiler gas flow, approximately 15 percent. The bag filter gas flow is ducted from the mechanical cyclone therefore there is some treatment of the gas prior to the filter. The filter is a Pulse Flow PF SQ4508 consisting of a housing containing 144, 4 1/2 inch diameter by 8 foot, filter bags. The filter provides a total filter area of 1395 ft.^{2} with a design air-to-cloth ratio of 6.45 scfm/ft^2.

Four particulate emission tests were performed using EPA Method 17, a modification of Method 5.

During the tests the filter received approximately 30% of the total boiler gas flow. The boiler loading averaged 77 percent.[33]

PLANT GGG

TEST SUMMARY SHEETS (Particulates Only)[33]

Test Number	One	Two	Three	Four	Average
General Data					
Date	12/4/79	12/4/79	12/5/79	12/5/79	
Time					
Isokinetic Ratio (%)					
Boiler Load (% of rating)	80	78	74	76	77
Percent flow to baghouse*	30	30	30	30	30
Gas Data					
Velocity (mps)					
Velocity (fps)					
Flow (dnm^3/min)	600	580	564	572	579
Flow (dscfm)	21200	20500	19900	20200	20450
Temperature (°C)	230	231	224	228	228
Temperature (°F)	446	448	435	442	443
Pressure (inches W.G.)					
Moisture (%)					
Particulate Emissions					
g/dnm^3	0.11	0.09	0.11	0.09	0.10
gr/dscf	0.05	0.04	0.05	0.04	0.05
ng/J	55.9	55.9	55.9	43.0	52.7
lb/10^6 Btu	0.13	0.13	0.13	0.10	0.12
Fuel Analysis					
Heating Value (kJ/kg)					31381
Heating Value (Btu/lb)					13689
% Ash					4.28
% Sulfur					0.94
Average Opacity (%)					

* Average for all tests.

C.2 VISIBLE EMISSION DATA

Table C.2-1 lists visible emission data collected with transmissometers, while Table C.2-2 lists data obtained with EPA Method 9 visual methods.

TABLE C.2-1. OPACITY TRANSMISSOMETER DATA

Type of Boiler	Boiler Load 10^3 lb/hr[a]	Control Equipment	Particulate Mass Loading ng/J	Particulate Mass Loading lb/10^6 Btu	Opacity Percent
Pulverized Coal (Plant KK)	168	Fabric Filter	12.8	0.030	0
	166		8.4	0.020	0
	164		7.8	0.018	0
	215		7.8	0.018	0
	173		6.4	0.015	0
	189		4.3	0.010	0
	167		2.5	0.006	0
	185		3.2	0.007	0
	170		3.2	0.008	0
Spreader Stoker (Plant UU)	94	Mechanical Collector	670	1.55	35
	96		610	1.42	35
	95		600	1.40	25
	94		570	1.34	30
	94		540	1.26	25
	88		500	1.16	25
	95		450	1.05	25
	93		450	1.05	25
	95		420	0.99	25
Spreader Stoker (Plant VV)[34]	70	Mechanical Collector	400	0.931	10
	70		360	0.839	10
	72		360	0.842	10
	71		350	0.827	10
	56		300	0.690	10
	61		260	0.596	12
	60		250	0.577	11
	70		240	0.553	10
	69		220	0.516	10
	49		220	0.513	10
	52		180	0.426	10
	16		160	0.380	11
Spreader Stoker (Plant EE #2)	50	Mechanical Collector and Fabric Filter	3.9	0.009	<10
	49		6.5	0.015	<10
	49		8.6	0.020	<10
Spreader Stoker (Plant EE #4)	77	Mechanical Collector amd Fabric Filter	3.0	0.007	<10
	78		4.3	0.010	<10
	78		5.6	0.013	<10

TABLE C.2-1. (CONTINUED)

Type of Boiler	Boiler Load 10^3 lb/hr[a]	Control Equipment	Particulate Mass Loading ng/J	Particulate Mass Loading lb/10^6 Btu	Opacity Percent
Spreader Stoker (Plant EE #5)	145	Mechanical Collector and Fabric Filter	7.7	0.018	<10
	144		16	0.038	<10
Vibrating Grate Stoker (Plant R)	78	Mechanical Collector	320	0.754	35
	78		290	0.667	19
	55		260	0.595	11
	77		250	0.574	23
	58		240	0.557	30
	80		210	0.490	29
	57		210	0.488	12
	79		180	0.424	19
	71		180	0.421	19
	78		170	0.393	32
	59		160	0.372	12
	57		150	0.354	12
	59		140	0.328	12
	58		140	0.319	12
Spreader Stoker (Plant BBB)	55	Sidestream Separator	75	0.175	6
	53		74	0.173	6
	50		74	0.171	6
	56		72	0.167	6
	55		72	0.166	6
	54		71	0.164	6
	51		66	0.154	6
	55		65	0.151	6
Spreader Stoker (Plant EEE) Boiler #1	37	Sidestream Separator	53	0.123	10
	34		52	0.120	5
	36		50	0.117	5
Spreader Stoker (Plant EEE) Boiler #3	40	Sidestream Separator	71	0.165	0
	41		66	0.153	0
	42		64	0.149	0
	42		62	0.144	0
	40		61	0.143	0
	40		59	0.136	0
	41		54	0.126	0
	40		53	0.123	0

[a] Steam output from boiler.

TABLE C.2-2. OPACITY EPA REFERENCE METHOD 9

Type of Boiler	Boiler Load 10^3 lb/hr[a]	Control Equipment	Particulate Mass Loading		Opacity Percent[b]
			ng/J	lb/10^6 Btu	
Pulverized Coal (Plant C)	250	Fabric Filter	18	0.043	2.5[c]
	250		15	0.034	2.5
	250		14	0.032	2.5
Spreader Stoker (Plant JJ) (Pulse Jet Cleaning Mode)	80	Fabric Filter	6	0.013	0
Spreader Stoker (Plant JJ) (Reverse Air Cleaning Mode)	75	Fabric Filter	5	0.011	<1
			4	0.010	0
			4	0.009	0
Spreader Stoker (Plant J2)	45	Fabric Filter	9	0.020	0
			9	0.021	<1[c]
			10	0.023	<1
			23	0.054	<1
Pulverized Coal (Plant II)	52	Scrubber	67	0.157	<1
			47	0.109	<1[c]
			28	0.066	<1
			21	0.048	0
Residual Oil Fired (Plant HHH)	3744	ESP	44	0.102	5.7[d]
	3789		30	0.070	<1[d]
	3735		28	0.065	8.3[d]
Spreader Stoker (Plant K-Boiler #9)	124	ESP	5.6	0.013	2.3
	126		5.2	0.012	<1
	124		4.3	0.010	<1
Underfeed Stoker (Plant H)	31	Mechanical Collector	30	0.09	<5
	27		30	0.07	<5
	28		26	0.06	<5
Spreader Stoker (Plant XX)	75	Mechanical Collector	220	0.506	17
	75		170	0.392	17
	75		210	0.494	22
	60		110	0.253	22

TABLE C.2-2. (CONTINUED)

Type of Boiler	Boiler Load 10^3 lb/hr[a]	Control Equipment	Particulate Mass Loading ng/J	Particulate Mass Loading lb/10^6 Btu	Opacity Percent[b]
Spreader Stoker (Plant FFF)	90	Sidestream Separator	70	0.156	<1
Spreader Stoker (Plant DDD)	31	Sidestream Separator	56	0.130	0
	31		55	0.128	0
	31		50	0.116	0
	31		45	0.104	0

[a] Steam output from boiler.

[b] Average of six-minute readings.

[c] Included a soot blow cycle.

[d] Soot blown continuously.

C.3 SO_2 EMISSION REDUCTION DATA

This section presents continuous monitoring data for eight industrial boiler wet FGD systems, one lime spray drying FGD system, and one fluidized-bed combustion system. The test data for five of the wet FGD systems were presented and discussed in Chapter 4 with regard to the level of SO_2 removal achievable with well designed, operated, and maintained FGD systems. Test data for the first large scale lime spray drying system is also presented and discussed. This section contains daily test results for each of these sites as well as the continuous monitoring data for three wet FGD systems that were, for various reasons, not considered to be representative of well designed and operated FGD systems. The reasons why these latter sites were not considered to be representative are documented in their respective site descriptions.

All the continuous monitoring tests of FGD systems were conducted by EPA. At the start of each test program, the continuous monitors were subjected to performance specification tests as delineated in 40 CFR 60, Appendix B (proposed revisions as of 10 October 1979). All sampling and analysis during the performance tests were performed according to EPA 40 CFR 60 Appendix A, Methods 1 through 6. SO_2 emission rates in ng/J ($lb/10^6$ Btu) were calculated from measured gas stream concentrations combined with ultimate analyses and heating values of the fuel fired at each site. The SO_2 removal efficiencies were then determined by comparison of inlet and outlet emission rates. Only test days with more than 18 hours of test data are reported.

Each site description that follows provides a brief process description and daily average monitoring results in both tabular and graphical form. References for original tests can be found at the end of this Appendix.

Location I

The FGD system monitored at plant location I is a Peabody tray and quench water scrubber. The scrubbing medium is a 50 weight percent sodium hydroxide (NaOH) aqueous solution with a 35 gallon per minute make up. A scrubber handling flue gases from a 150,000 lbs. steam/hr capacity Babcock and Wilcox (B&W) pulverized coal boiler was monitored. The boiler is fired using Southern Illinois subbituminous coal with a sulfur content between 3.55 to 3.73 weight percent.

The daily averaged test results are presented in Table C.3-1 to C.3-3. Continuous monitoring data was obtained for 30 test days. The hourly averaged boiler loadings ranged from 55,000 to 120,000 lbs/hr. with an average of about 72,000 lbs/hr during the test period.[35] Figure C.3-1 illustrates daily average SO_2 removal efficiency, boiler load, and scrubbing solution pH.

TABLE C.3-1. DAILY AVERAGE SO_2 REMOVAL RESULTS SODIUM SCRUBBING PROCESS - LOCATION I[a] [36]

	SO_2 Emission Rate at Scrubber Inlet		SO_2 Emission Rate at Scrubber Outlet		Percent SO_2 Removal
Test Day [a]	ng/J	lb/million/Btu	ng/J	lb/million/Btu	
1	2380	5.5	55	0.1	97.7
2	2377	5.5	58	0.1	97.6
3	2403	5.6	59	0.1	97.6
4	2385	5.5	64	0.1	97.3
5	2274	5.3	54	0.1	97.3
6	2341	5.4	69	0.2	97.0
7	2406	5.6	83	0.2	96.5
8	2420	5.6	96	0.2	96.1
9	2396	5.6	108	0.3	95.5
10	2404	5.6	81	0.2	96.7
11	2392	5.6	74	0.2	96.9
12	2433	5.7	85	0.2	96.5
13	2450	5.7	90	0.2	96.3
14	2372	5.5	83	0.2	96.5
15	2433	5.7	87	0.2	96.4
16	2461	5.7	96	0.2	96.1
17	2420	5.6	83	0.2	96.6
18	2421	5.6	99	0.2	95.9
19	2376	5.5	81	0.2	96.6
20	2365	5.5	91	0.2	96.2
21	2354	5.5	90	0.2	96.2
22	2335	5.4	92	0.2	96.1
23	2480	5.8	80	0.2	96.7
24	2724	6.3	112	0.3	95.4
25	2229	5.2	267	0.6	88.3
26	2132	5.0	90	0.2	95.7
27	2109	4.9	85	0.2	96.0
28	2125	4.9	86	0.2	96.0
29	2072	4.8	62	0.1	96.9
30	1961	4.6	62	0.1	96.8
30 Day Average	2348	5.5	87	0.2	96.2

[a] 18 Hours/day minimum test time.

TABLE C.3-2. DAILY SUMMARY OF HOURLY BOILER LOADS SODIUM SCRUBBING PROCESS - LOCATION I[36]

Test Day[a]	Minimum Hourly Boiler Load (1000 lb steam/hr)	24-Hour Average Boiler Load (1000 lb steam/hr)	Maximum Hourly Boiler Load (1000 lb steam/hr)
1	77	81	86
2	70	77	81
3	75	79	98
4	73	83	120
5	73	77	80
6	81	84	90
7	66	68	75
8	61	69	80
9	70	73	75
10	67	70	73
11	70	73	77
12	61	67	72
13	60	66	68
14	70	70	70
15	55	58	60
16	55	55	55
17	55	55	55
18	60	73	80
19	78	81	85
20	65	67	70
21	65	71	80
22	70	79	82
23	78	80	82
24	70	78	80
25	70	77	80
26	65	65	70
27	60	76	80
28	60	70	85
29	65	65	65
30	50	62	110

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[a] 18 Hours/day minimum test time.

TABLE C.3-3. DAILY SUMMARY OF pH LEVELS SODIUM SCRUBBING PROCESS - LOCATION I[37]

Test Day[a]	Minimum pH Reading	Daily Average pH Level	Maximum pH Reading
1	7.8	8.0	8.2
2	7.7	8.1	8.3
3	7.8	7.9	8.2
4	7.7	8.0	8.3
5	7.8	8.0	8.1
6	7.8	7.9	8.0
7	7.9	8.0	8.2
8	8.2	8.2	8.2
9	7.9	8.0	8.1
10	8.1	8.1	8.2
11	7.8	8.1	8.7
12	8.2	8.8	9.4
13	8.0	8.1	8.1
14	8.0	8.0	8.0
15	8.0	8.0	8.0
16	8.1	8.1	8.1
17	8.0	8.0	8.0
18	7.8	7.8	7.9
19	-	7.9	-
20	-	8.5	-
21	8.0	8.1	8.1
22	7.8	8.0	8.3
23	-	8.0	-
24	-	8.3	-
25	-	8.2	-
26	8.0	8.4	8.8
27	-	8.2	-
28	-	8.2	-
29	8.0	8.2	8.4
30	7.8	8.1	8.4

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[a] No minimum or maximum readings are given on those test days for which only one reading was taken.

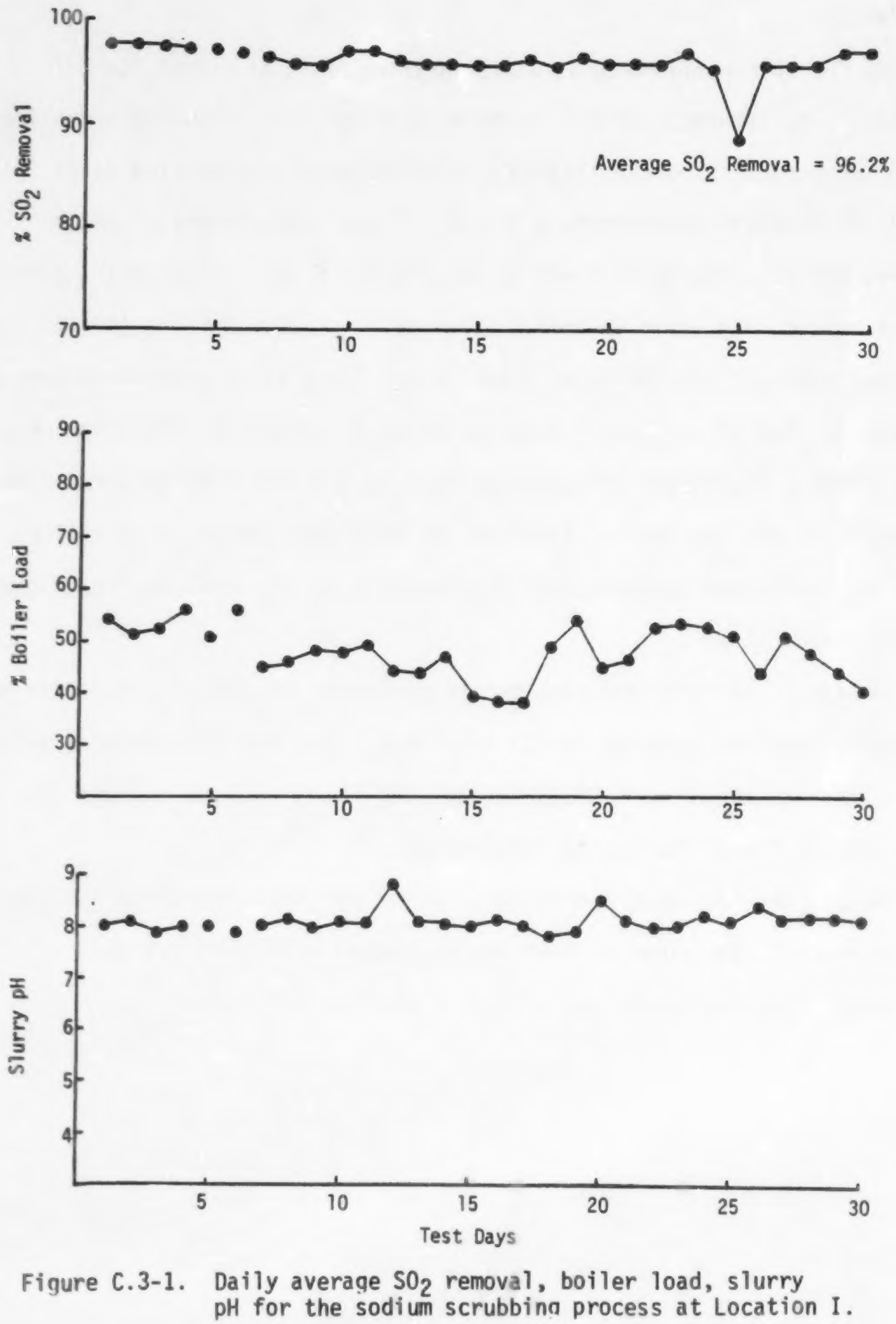

Figure C.3-1. Daily average SO_2 removal, boiler load, slurry pH for the sodium scrubbing process at Location I.

Location II

The FGD system monitored at plant location II is an Airpol Venturi scrubber. The scrubbing medium is an aqueous solution of sodium hydroxide (NaOH) and sodium carbonate (Na_2CO_3). The scrubber handles flue gases from two oil-fired steam generators, a hog fuel-fired steam generator and a recovery boiler. The boilers are fired with No. 6 fuel oil containing four percent sulfur with Gross Calorific Value (GCV) of 39,929 kJ/kg (17,167 Btu/lb). Each unit produces 100,000 lb of steam/hour. These units operate in tandem with the hog-fueled unit which supplied up to 50 percent of the total process steam demand. The amount of steam produced by the hog-fired unit depended on the supply of the hog fuel. Therefore, under normal operating conditions, there were large and unpredictable fluctuations in the steam demand on the two oil-fired units.

The daily averaged test results are presented in Table C.3-4. Continuous monitoring data was obtained for 22 test days. The hourly combined averaged boiler loadings ranged from 35,000 to 265,000 lbs/hr with an average of about 103,000 lbs/hr during the test period.[38]

Despite the fact that average SO_2 removal for the test period was greater than 90 percent, the wide fluctuations in removal efficiency are not considered to be representative of a well-operated FGD system.[39]

TABLE C.3-4. DAILY AVERAGE SO_2 REMOVAL RESULTS SODIUM SCRUBBING PROCESS - LOCATION II[40]

Test Day[a]	SO_2 Emission Rate at Scrubber Inlet		SO_2 Emission Rate at Scrubber Outlet		Percent SO_2 Removal
	ng/J	$\frac{\text{Lb}}{\text{Million Btu}}$	ng/J	$\frac{\text{Lb}}{\text{Million Btu}}$	
1	1827	4.3	52.	0.1	97.2
2	1830	4.3	27.	0.1	98.5
3	1829	4.3	480.	1.1	73.7
4	1986	4.6	46.	0.1	97.7
5	2088	4.9	149.	0.3	92.9
6	2334	5.4	67.	0.2	97.1
7	2220	5.2	140.	0.3	93.7
8	1960	4.6	119.	0.3	93.9
9	2116	4.9	28.	0.1	98.7
10	2224	5.2	109.	0.3	95.1
11	2089	4.9	99.	0.2	95.3
12	1882	4.4	544.	1.3	71.1
13	1591	3.7	12.	0.0	99.3
14	1429	3.3	23.	0.1	98.4
15	1692	3.9	15.	0.0	99.1
16	1532	3.6	347.	0.8	77.3
17	2101	4.9	28.	0.1	98.7
18	1670	3.9	24.	0.1	98.6
19	1803	4.2	43.	0.1	97.6
20	1889	4.4	752.	1.7	60.2
21	1627	3.8	338.	0.8	79.2
22	2818	6.6	69.	0.2	97.6
22 Day Average	1934	4.5	160	0.4	91.7

[a] 18 hours/day minimum test time

Location III

Two FGD systems were monitored at plant location III. Both systems consist of dilute double alkali scrubbing in valve tray type absorbers supplied by Koch Engineering Company. SO_2 in the flue gas is absorbed by a regenerated caustic soda solution (0.1 M NaOH), forming a solution of soluble sodium salts. The absorber has a quench spray section at the inlet and full diameter chevron mist eliminators at the outlet. A portion of the circulating liquor containing a mixture of sodium sulfate is bled to a reactor/clarifier system where active alkali is regenerated by reacting the solution with a slurry of lime. The precipitated solids are further reacted and concentrated in a clarifier.

The individual scrubbers handle flue gases from coal-fired boilers No. 1 and No. 3. Each boiler is a spreader-stoker unit with a maximum rated capacity of 100,000 and 60,000 lbs/hour of steam, respectively, for boilers No. 1 and No. 3.[41] Normal burning of eastern coal containing 1.7 to 2.7 percent sulfur, plus occasional lower sulfur waste oil results in flue gas generally containing 800 to 1,300 ppm of SO_2.

The daily average test results are presented in Tables C.3-5 through C.3-10. Continuous monitoring data was obtained for 17 and 24 test days for the FGD systems on boiler No. 1 and No. 3, respectively. Figures C.3-2 and C.3-3 present daily SO_2 removal boiler load, and slurry pH for the two boilers.

TABLE C.3-5. DAILY AVERAGE SO_2 REMOVAL RESULTS DUAL ALKALI PROCESS LOCATION III (BOILER NO. 1)[42]

Test Day[a]	SO_2 Emission Rate at Scrubber Inlet		SO_2 Emission Rate at Scrubber Outlet		Percent SO_2 Removal
	ng/J	Lb/Million Btu	ng/J	Lb/Million Btu	
1	1659	3.8	194	0.5	88.2
2	1720	4.0	165	0.4	90.3
3	1698	4.0	163	0.4	90.4
4	1634	3.8	117	0.3	92.8
5	1594	3.7	97	0.2	93.6
6	1320	3.1	134	0.3	89.9
7	1235	2.9	93	0.2	92.4
8	1539	3.6	138	0.3	90.8
9	1806	4.2	101	0.2	94.6
10	2000	4.7	137	0.3	93.0
11	1680	3.9	156	0.4	90.6
12	1670	3.9	81	0.2	95.2
13	1619	3.8	172	0.4	89.4
14	1722	4.0	213	0.5	87.6
15	1811	4.2	134	0.3	92.6
16	1564	3.6	110	0.3	93.0
17	1706	4.0	135	0.3	92.1
17 Day Average	1646	3.8	138	0.3	91.6

[a] 18 Hours/day minimum test time.

TABLE C.3-6. DAILY AVERAGE SO_2 REMOVAL RESULTS
DUAL ALKALI PROCESS
LOCATION III (BOILER NO. 3)[42]

Test Day [a]	SO_2 Emission Rate at Scrubber Inlet		SO_2 Emission Rate at Scrubber Outlet		Percent SO_2 Removal
	ng/J	Lb / Million Btu	ng/J	Lb / Million Btu	
1	1534	3.6	62	0.1	95.9
2	1223	2.9	64	0.1	94.8
3	1246	2.9	78	0.2	93.7
4	1247	2.9	70	0.2	94.5
5	1180	2.8	82	0.2	93.0
6	1275	3.0	73	0.2	94.1
7	1284	3.0	37	0.1	97.1
8	1215	2.8	40	0.1	96.7
9	1634	3.8	446	1.0	73.6
10	1678	3.9	342	0.8	79.2
11	1892	4.4	201	0.5	89.3
12	1631	3.8	85	0.2	94.9
13	1647	3.8	61	0.1	96.3
14	1715	4.0	70	0.2	95.9
15	1934	4.5	153	0.4	92.2
16	1997	4.6	177	0.4	91.1
17	2285	5.3	110	0.3	95.1
18	2084	4.8	137	0.3	93.2
19	1648	3.8	133	0.3	92.0
20	1652	3.8	139	0.3	91.6
21	1707	4.0	132	0.3	92.3
22	1628	3.8	108	0.3	93.4
23	1561	3.6	128	0.3	91.9
24	1647	3.8	150	0.3	91.1
24 Day Average	1606	3.7	128	0.3	92.2

[a] 18 Hours/day minimum test time.

TABLE C.3-7. DAILY SUMMARY OF HOURLY BOILER LOADS DUAL ALKALI PROCESS LOCATION III (BOILER NO. 1)[42]

Test Day[a]	Minimum Hourly Boiler Load (1000 lb steam/hr)	24-Hour Average Boiler Load (1000 lb steam/hr)	Maximum Hourly Boiler Load (1000 lb steam/hr)
1	60	74	88
2	60	80	96
3	65	73	80
4	67	74	80
5	60	76	93
6	55	68	84
7	53	67	76
8	52	68	89
9	55	66	76
10	52	56	63
11	47	53	60
12	60	71	86
13	53	67	83
14	42	65	82
15	49	54	59
16	53	67	81
17	50	65	76

[a] 18 Hours/day minimum test time.

TABLE C.3-8. DAILY SUMMARY OF pH LEVELS DUAL ALKALI PROCESS LOCATION III (BOILER NO. 1)[43]

Test Day	Minimum pH Reading	Daily Average pH Level	Maximum pH Reading
1	6.0	6.0	6.0
2	6.0	6.0	6.0
3	6.0	6.0	6.0
4	6.0	6.0	6.0
5	5.6	5.8	6.0
6	5.8	5.9	6.0
7	6.0	6.0	6.0
8	6.0	6.0	6.0
9	5.7	6.0	6.0
10	5.8	5.9	6.0
11	5.9	6.1	6.3
12	5.7	6.0	6.2
13	5.9	6.1	6.3
14	6.0	6.0	6.0
15	6.0	6.0	6.0
16	6.0	6.1	6.5
17	6.0	6.0	6.0

TABLE C.3-9. DAILY SUMMARY OF HOURLY BOILER LOADS DUAL ALKALI PROCESS LOCATION III (BOILER NO. 3)[42]

Test Day[a]	Minimum Hourly Boiler Load (1000 lb steam/hr)	24-Hour Average Boiler Load (1000 lb steam/hr)	Maximum Hourly Boiler Load (1000 lb steam/hr)
1	3	32	43
2	22	34	48
3	25	34	40
4	26	36	46
5	34	39	43
6	37	40	43
7	36	40	42
8	38	41	42
9	30	41	56
10	28	37	47
11	27	38	49
12	5	42	53
13	38	43	50
14	19	38	45
15	38	46	57
16	34	42	50
17	29	39	50
18	27	39	50
19	29	35	45
20	25	32	42
21	24	32	41
22	20	31	39
23	28	35	43
24	24	32	42

[a] 18 Hours/day minimum test time.

TABLE C.3-10. DAILY SUMMARY OF pH LEVELS
DUAL ALKALI PROCESS
LOCATION III (BOILER NO. 3)[43]

Test Day[a]	Minimum pH Reading	Daily Average pH Level	Maximum pH Reading
1	5.2	5.8	6.2
2	5.0	6.0	6.5
3	5.8	6.0	6.1
4	5.8	6.0	6.0
5	5.8	6.0	6.2
6	5.8	5.9	6.0
7	5.9	6.0	6.2
8	5.8	6.0	6.2
9	6.0	6.0	6.0
10	-	-	-
11	-	-	-
12	-	-	-
13	-	-	-
14	-	-	-
15	5.9	6.0	6.1
16	5.9	6.0	6.2
17	6.0	6.1	6.1
18	6.0	6.0	6.0
19	6.0	6.0	6.0
20	4.7	5.8	6.1
21	6.0	6.0	6.1
22	6.0	6.0	6.1
23	6.0	6.0	6.0
24	6.0	6.0	6.0

[a] No pH data available for test days 10 through 14.

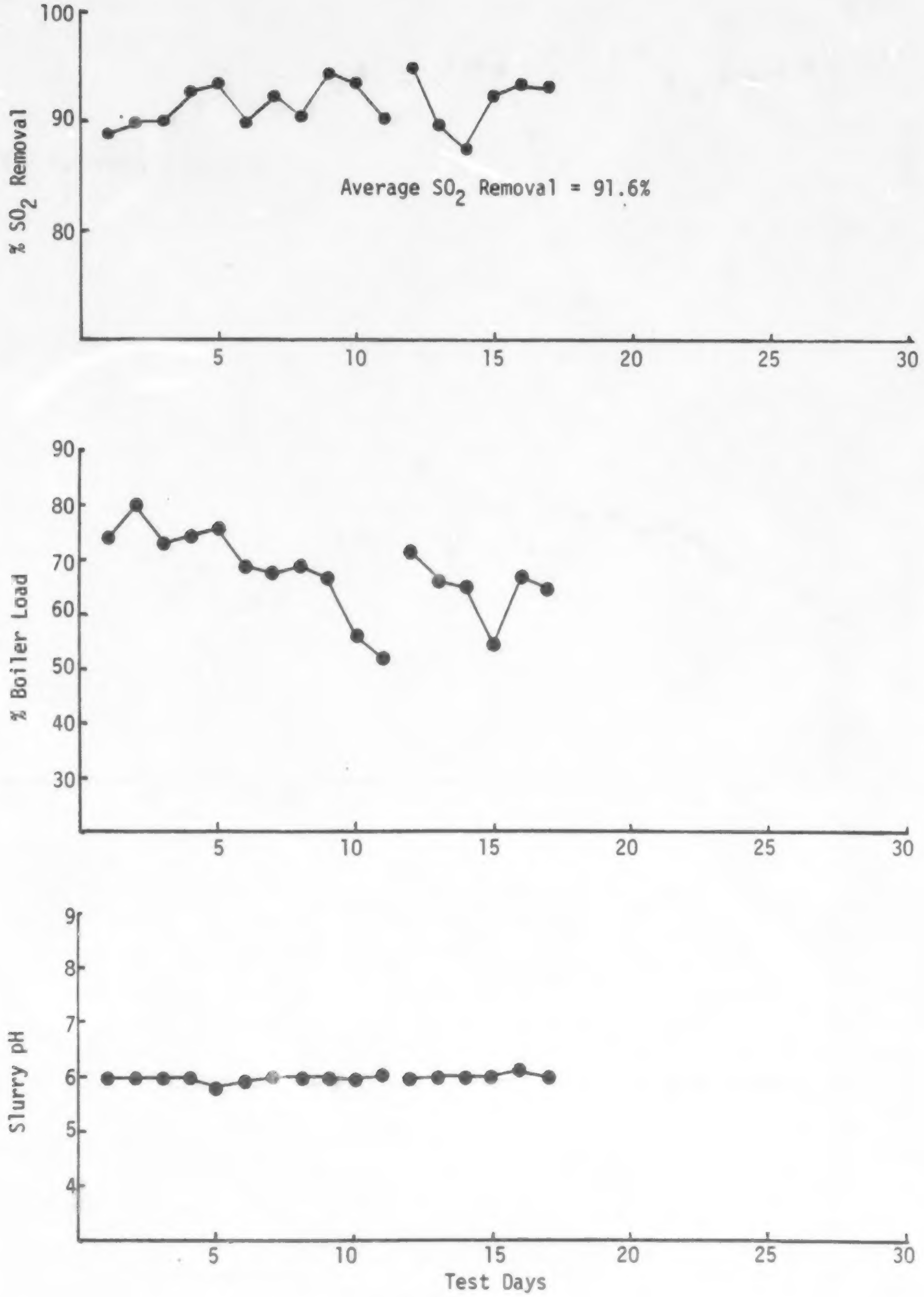

Figure C.3-2. Daily average SO_2 removal, boiler load, and slurry pH for the dual alkali scrubbing process at Boiler No. 1, Location III.

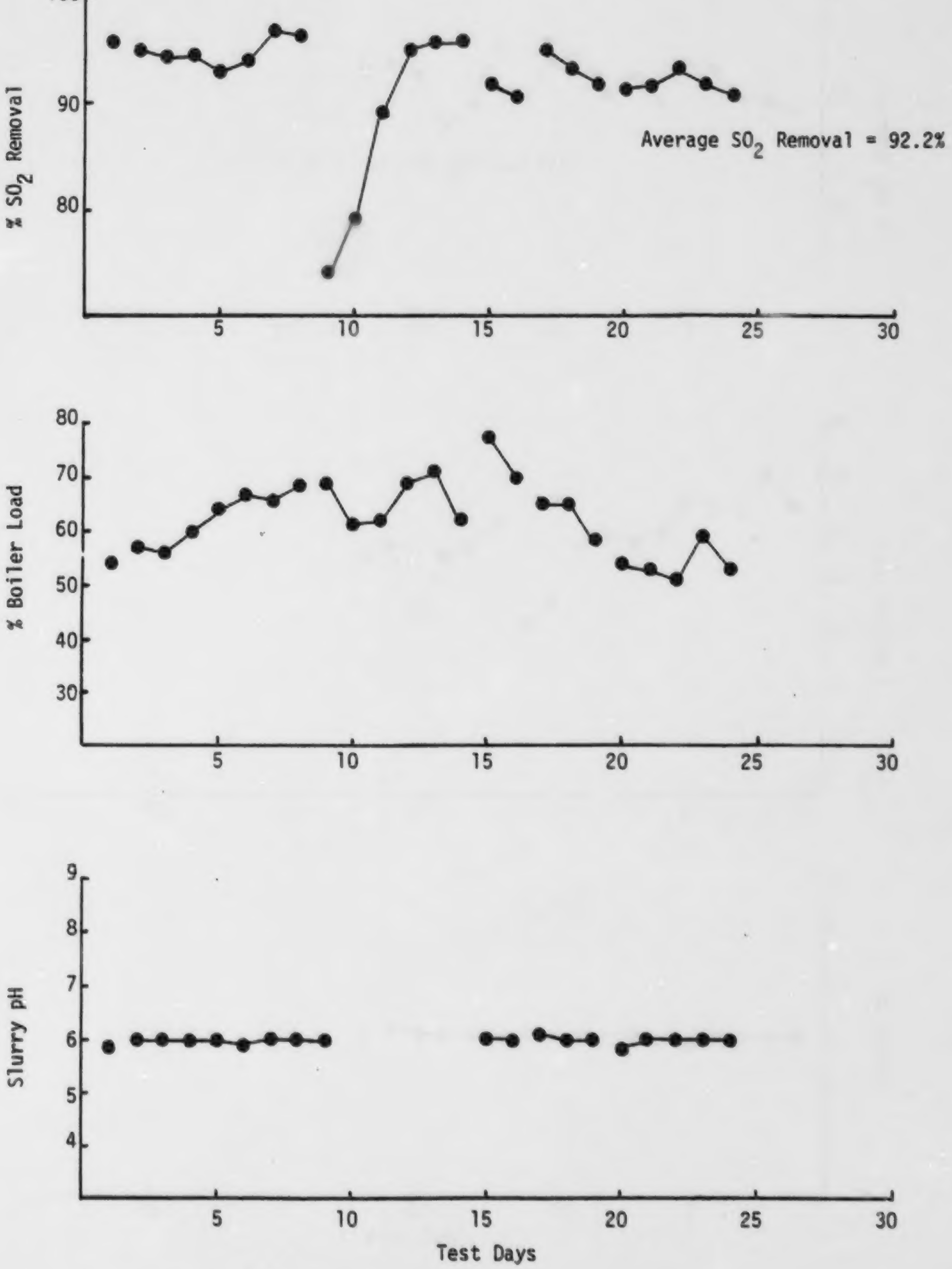

Figure C.3-3. Daily average SO_2 removal, boiler load, and slurry pH for scrubbing process at Boiler No. 3 Location III.

Location IV - Lime System

Three data sets were taken on a lime/limestone FGD system at location IV. One of the tests monitored the system under lime sorbent operations and the two other tests monitored the system while it operated using limestone as a sorbent. In one of the two limestone tests, adipic acid was added to improve SO_2 removal efficiency.

Particulates are removed from the flue gas in a mechanical collector upstream of the absorber. The absorber is a two-stage unit with fresh solvent make-up being introduced at the second stage. Flue gas from the absorber enters a cyclonic mist eliminator before going to the stack.

The scrubber system was designed to treat the combined flue gas from seven small stoker boilers at the peak winter load of approximately 210×10^6 Btu/hr.[44] Typical fuel burned at the facility is mid-west coal with a sulfur content of about 3.5 percent. The system has essentially unlimited turndown capability since it mixes air with flue gas to maintain a constant flue gas rate at low boiler loads. Consequently, SO_2 concentrations will vary from about 200 to 2000 ppm depending upon the boiler load. SO_2 emissions averaged 194 ng/J during the tests.

The daily average test results for operation with lime sorbent are presented in Tables C.3-11 through C.3-13. Continuous monitoring data was obtained for 29 days with overall average SO_2 removal of 91.2. Figure C.3-4 shows the daily SO_2 removal boiler load, and slurry pH levels.

TABLE C.3-11. DAILY AVERAGE SO_2 REMOVAL RESULTS LIME SLURRY PROCESS LOCATION IV[45]

Test Day [a]	SO_2 Emission Rate at Scrubber Inlet		SO_2 Emission Rate at Scrubber Outlet		Percent SO_2 Removal
	ng/J	Lb/Million Btu	ng/J	Lb/Million Btu	
1	2021	4.7	211	0.5	89.7
2	2175	5.1	230	0.5	89.4
3	2293	5.3	160	0.4	93.0
4	2277	5.3	179	0.4	92.2
5	2245	5.2	237	0.6	89.4
6	2344	5.5	194	0.5	91.6
7	2333	5.4	260	0.6	88.8
8	2310	5.4	186	0.4	92.0
9	2355	5.5	146	0.3	93.8
10	2318	5.4	189	0.4	91.8
11	2220	5.2	124	0.3	94.4
12	2334	5.4	94	0.2	96.0
13	2432	5.7	194	0.5	92.0
14	2418	5.6	127	0.3	94.7
15	2390	5.6	128	0.3	94.6
16	2255	5.2	205	0.5	91.0
17	2272	5.3	201	0.5	91.2
18	2318	5.4	218	0.5	90.6
19	2299	5.4	216	0.5	90.6
20	2262	5.3	199	0.5	91.3
21	2145	5.0	131	0.3	93.8
22	2273	5.3	185	0.4	91.9
23	2359	5.5	213	0.5	90.9
24	2116	4.9	150	0.4	93.4
25	2207	5.1	294	0.7	86.7
26	2245	5.2	279	0.6	87.6
27	2125	4.9	285	0.7	86.8
28	1990	4.6	149	0.3	92.4
29	1927	4.5	190	0.4	90.6
29 Day Average	2250	5.2	192	0.4	91.5

[a] 18 Hours/day minimum test time.

TABLE C.3-12. DAILY SUMMARY OF HOURLY BOILER LOADS LIME SLURRY PROCESS LOCATION IV[45]

Test Day[a]	Minimum Hourly Boiler Load (million Btu/hr)	24-Hour Average Boiler Load (million Btu/hr)	Maximum Hourly Boiler Load (million Btu/hr)
1	99	106	118
2	98	107	119
3	102	110	120
4	100	108	120
5	104	113	125
6	106	113	127
7	103	116	131
8	94	110	118
9	102	112	119
10	99	113	122
11	99	112	123
12	97	109	118
13	99	113	129
14	78	112	126
15	72	93	109
16	111	120	132
17	96	115	127
18	98	113	132
19	106	121	134
20	109	125	136
21	90	110	128
22	81	102	117
23	105	116	134
24	90	104	127
25	86	107	127
26	88	99	109
27	90	97	106
28	72	82	95
29	78	93	105

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[a] 18 Hours/day minimum test time.

TABLE C.3-13. DAILY SUMMARY OF pH LEVELS
LIME SLURRY PROCESS
LOCATION IV[46]

Test Day	Minimum pH Reading	Daily Average pH Level	Maximum pH Reading
1	7.8	7.9	8.0
2	7.9	8.3	8.5
3	4.6	6.3	8.0
4	7.6	7.7	7.8
5	5.8	6.6	7.6
6	8.0	8.2	8.4
7	7.2	7.4	7.6
8	7.5	7.9	8.2
9	7.1	7.4	8.0
10	7.0	7.3	7.8
11	7.4	7.5	7.6
12	8.0	8.5	9.2
13	7.4	7.5	7.6
14	7.2	7.3	7.4
15	7.6	8.4	9.9
16	6.2	6.5	7.0
17	6.8	6.8	6.9
18	7.8	8.3	8.8
19	6.6	7.4	8.3
20	7.8	7.9	8.0
21	7.8	7.9	8.0
22	7.8	7.9	7.9
23	8.0	8.1	8.2
24	7.8	7.9	8.0
25	5.6	6.3	6.8
26	4.8	5.3	6.0
27	3.8	4.3	4.7
28	6.3	6.6	7.0
29	4.7	5.6	6.1

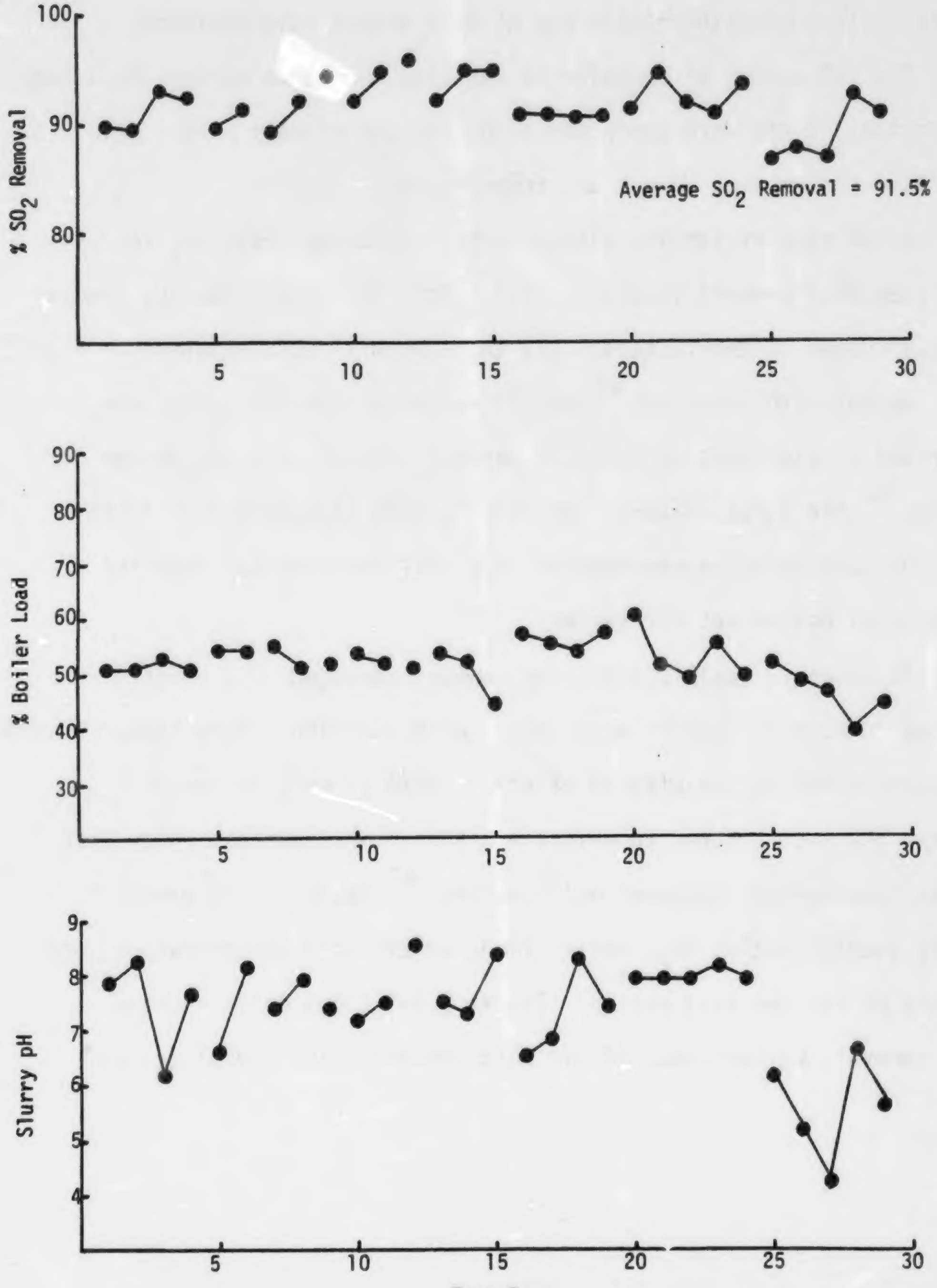

Figure C.3-4. Daily average SO_2 removal, boiler load, and slurry pH for lime slurry scrubbing process at Location IV.

Location IV - Limestone (with and without Adipic Acid Addition)

The FGD system at Location IV was also monitored during limestone operation. Tests were conducted both with and without adipic acid addition (References 47 and 48, respectively).

In 36 days of testing without adipic acid addition, SO_2 removal averaged 58.7 percent (Table C.3-14). This relatively low SO_2 removal is attributed to two factors: (1) the system is not designed for high SO_2 removal with limestone[47] and (2) evidence that the system was operated at gas flows of about 20 percent greater than the design value.[39] For these reasons, the results from limestone only tests are not considered representative of a well designed and operated industrial boiler wet FGD system.

As shown in Table C.3-15, SO_2 removal averaged 94.3 percent during 30 days of testing with adipic acid addition. This higher removal was attributed to the effects of adipic acid as well as the effort during the test program to maintain higher limestone feed rates than those used during limestone only testing.[47] Table C.3-16 presents daily average outlet SO_2, boiler load, adipic acid concentration, and slurry pH for the test period. Figure C.3-5 shows daily average SO_2 removal, boiler load, adipic acid concentration and slurry pH.

TABLE C.3-14. DAILY AVERAGE SO_2 REMOVAL RESULTS LIMESTONE SLURRY PROCESS LOCATION IV[48]

Test Day[a]	Emission Rate at Scrubber Inlet		Emission Rate at Scrubber Outlet		Percent SO_2 Removal
	ng/J	Lb/Million Btu	ng/J	Lb/Million Btu	
1	2351	5.5	1334	3.1	43.3
2	2705	6.3	1290	3.0	51.9
3	2792	6.5	912	2.1	66.8
4	2590	6.0	945	2.2	63.6
5	2670	6.2	1189	2.8	55.3
6	2652	6.2	1283	3.0	51.5
7	2681	6.2	1318	3.0	50.9
8	2705	6.3	1549	3.6	42.7
9	2691	6.3	1635	3.8	39.4
10	2762	6.4	1627	3.8	41.1
11	2983	6.9	1723	4.0	42.5
12	2922	6.8	1496	3.5	48.8
13	2740	6.4	1300	3.0	52.4
14	2551	5.9	1298	3.0	49.0
15	2764	6.4	1285	3.0	53.5
16	2744	6.4	1471	3.4	46.5
17	3043	7.1	1237	2.8	59.6
18	2897	6.7	1218	2.8	57.9
19	3038	7.1	1417	3.3	52.9
20	2435	5.7	1253	2.9	48.4
21	2340	5.4	1013	2.4	56.5
22	2484	5.8	928	2.2	62.5
23	2686	6.2	994	2.3	63.0
24	2672	6.2	1102	2.6	58.7
25	2662	6.2	989	2.3	62.8
26	2882	6.7	1101	2.6	61.1
27	3197	7.4	832	1.9	72.5
28	3646	8.5	806	1.9	76.4
29	3349	7.8	903	2.1	73.1
30	3386	7.9	1040	2.4	68.9
31	3296	7.7	946	2.2	71.2
32	3484	8.1	1002	2.3	71.4
33	3446	8.0	764	1.8	77.8
34	3227	7.5	758	1.8	76.5
35	3219	7.5	1012	2.4	68.3
36	2991	7.0	1256	2.9	57.9
36 Day Average	2880	6.7	1173	2.7	58.2

[a] 18 Hours/day minimum test time.

TABLE C.3-15. DAILY AVERAGE SO_2 REMOVAL RESULTS FOR LIMESTONE SLURRY PROCESS WITH ADIPIC ACID ADDITION - LOCATION IV[47]

Test Day[a]	Emission Rate at Scrubber Inlet		Emission Rate at Scrubber Outlet		Percent SO_2 Removal
	ng/J	$\frac{\text{lb}}{\text{Million Btu}}$	ng/J	$\frac{\text{lb}}{\text{Million Btu}}$	
1	1720	4.0	129	0.3	92.5
2	1333	3.1	60	0.1	95.5
3	1767	4.1	103	0.2	94.2
4	1642	3.8	129	0.3	92.1
5	1789	4.2	159	0.4	91.1
6	1793	4.2	116	0.3	93.5
7	2098	4.9	116	0.3	94.5
8	1879	4.4	90	0.2	95.2
9	1913	4.5	95	0.2	95.1
10	2661	6.2	194	0.5	92.7
11	2240	5.2	129	0.3	94.2
12	2128	5.0	138	0.3	93.5
13	2244	5.2	65	0.2	97.1
14	1995	4.6	108	0.3	94.6
15	2356	5.5	237	0.6	90.0
16	2137	5.0	138	0.3	93.6
17	2644	6.2	138	0.3	94.8
18	2085	4.9	125	0.3	94.0
19	1943	4.5	165	0.4	90.5
20	2765	6.4	262	0.6	90.5
21	2313	5.4	155	0.4	93.3
22	2077	4.8	60	0.1	97.1
23	2180	5.1	56	0.1	97.4
24	2060	4.8	77	0.2	96.2
25	2266	5.3	142	0.3	93.7
26	2214	5.2	82	0.2	96.3
27	2322	5.4	73	0.2	96.9
28	2365	5.5	90	0.2	96.2
29	2648	6.2	146	0.3	94.5
30	2176	5.1	69	0.2	96.8
30 Day Average	2125	4.9	122	0.3	94.3

[a] 18 Hours/day minimum test time.

TABLE C.3-16. DAILY AVERAGE BOILER LOAD, ADIPIC ACID CONCENTRATION AND SLURRY pH LIMESTONE SLURRY PROCESS WITH ADIPIC ACID ADDITION - LOCATION IV[47]

Test Day[a]	Boiler Load %	Adipic Acid Conc. (ppm)	Slurry pH
1	49	2305	4.7
2	55	2920	4.9
3	64	2090	4.7
4	64	2290	4.9
5	67	2150	-
6	60	1770	5.0
7	59	2165	5.0
8	49	1890	5.0
9	46	1855	4.8
10	50	1870	4.9
11	49	2050	4.7
12	62	3000	-
13	55	2680	5.2
14	48	2420	5.4
15	48	2200	5.4
16	48	2240	4.7
17	46	2150	5.2
18	48	2130	5.3
19	46	-	5.0
20	38	-	-
21	34	1920	-
22	37	1950	4.9
23	30	2040	5.5
24	30	2160	4.8
25	36	2200	4.7
26	33	2170	4.6
27	33	28[illegible]	5.1
28	32	2850	5.1
29	31	2510	4.6
30	36	2400	4.7
30 day average	46	2257	5.0
Minimum	30	1770	4.6
Maximum	67	3000	5.5

[a] 18 Hours/day minimum test time.

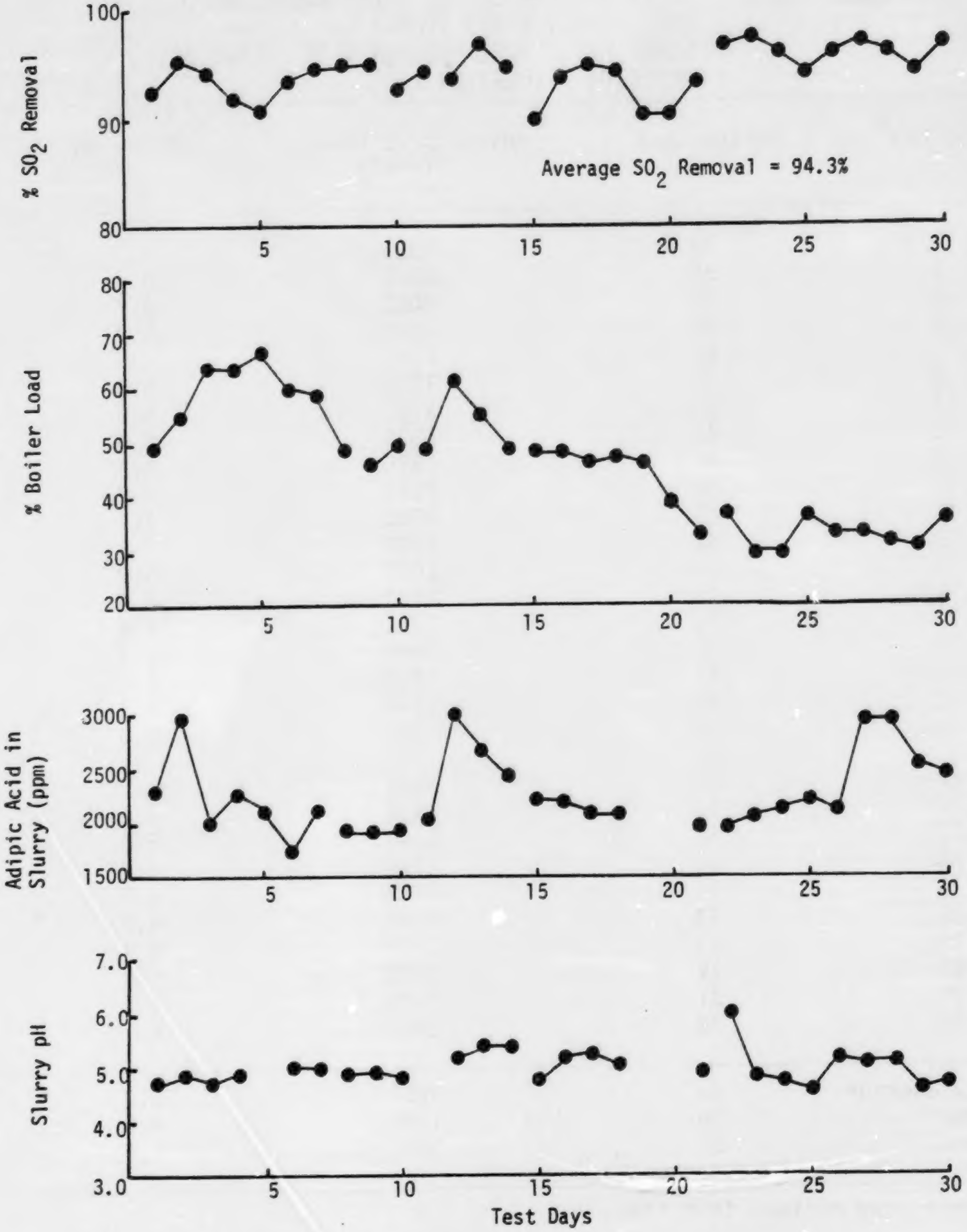

Figure C.3-5. Daily average SO$_2$ removal, boiler load, adipic acid concentration, and slurry pH for limestone system at Location IV.

Location V

The FGD system monitored at plant location V is a turbulent contact absorber (TCA) prototype installation. The TCA unit, constructed by Universal Oil Products, uses a fluid bed of low density plastic spheres that migrate between retaining grids. The scrubbing medium is a lime slurry. The pilot plant scale wet scrubber handles a side stream of the flue gases from a coal-fired boiler power station having 10 turbines.

The daily averaged test results are presented in Table C.3-17. Continuous monitoring data was obtained for 42 test days.[49]

Because this unit is designed and operated as pilot plant, it is not considered to be representative of industrial boiler wet FGD systems designed and operated for maximum SO_2 removal.[39]

TABLE C.3-17. DAILY AVERAGE SO_2 REMOVAL RESULTS LIME SLURRY PROCESS LOCATION V50

Test Day[a]	SO_2 Emission Rate at Scrubber Inlet ng/J	SO_2 Emission Rate at Scrubber Inlet Lb/Million Btu	SO_2 Emission Rate at Scrubber Outlet ng/J	SO_2 Emission Rate at Scrubber Outlet Lb/Million Btu	Percent SO_2 Removal
1	2541	5.9	264	0.6	89.6
2	2566	6.0	289	0.7	88.8
3	2549	5.9	306	0.7	88.0
4	2331	5.4	283	0.7	88.0
5	2270	5.3	237	0.6	89.7
6	2589	6.0	354	0.8	86.4
7	2588	6.0	380	0.9	85.5
8	2572	6.0	395	0.9	84.6
9	2449	5.7	347	0.8	85.8
10	2460	5.7	331	0.8	86.5
11	2266	5.3	247	0.6	89.1
12	2393	5.6	215	0.5	91.0
13	2274	5.3	240	0.6	89.5
14	2546	6.0	326	0.8	87.2
15	2711	6.3	314	0.7	88.4
16	2616	6.1	301	0.7	88.5
17	2322	5.4	227	0.5	90.5
18	2532	5.9	255	0.6	90.1
19	2250	5.2	194	0.5	91.4
20	2365	5.5	233	0.5	90.3
21	1961	4.6	160	0.4	92.1
22	2150	5.0	200	0.5	91.1
23	2440	5.7	253	0.6	89.7
24	2295	5.4	229	0.5	90.0
25	2313	5.4	331	0.8	85.9
26	1680	3.9	164	0.4	90.2
27	2163	5.0	270	0.6	88.0
28	2053	4.8	222	0.5	89.2
29	2132	5.0	351	0.8	83.7
30	2360	5.5	415	1.0	82.5
31	2635	6.1	367	0.9	86.1
32	2617	6.1	350	0.8	86.6
33	2594	6.0	309	0.7	88.1
34	2580	6.0	295	0.7	88.5
35	2579	6.0	319	0.7	87.6
36	2580	6.0	375	0.9	85.5
37	2315	5.4	258	0.6	88.9
38	2365	5.5	255	0.6	89.2
39	2486	5.8	280	0.7	88.8
40	2549	5.9	308	0.7	88.0
41	2225	5.2	210	0.5	90.9
42	2061		172	0.4	91.7
42 Day Average	2389	5.6	282	0.7	88.4

[a] 18 Hours/day minimum test time.

Location VI

The FGD system monitored at plant location VI is a spray drying scrubber. The scrubbing sorbent is a 26 percent high quality lime (90-94% calcium oxide) slurry. Approximately 2 percent sulfur coal was burned during most of the test period. Efficiencies found when the daily inlet SO_2 concentrations are high (above 4.0 $lb/10^6$ Btu) average 75 percent.[51]

The daily averaged test results are presented in Table C.3-18 for the 23 test days. During this period, boiler load averaged 114 million Btu/hr, with hourly loads ranging from 12 to 152 million Btu/hr.[52] Figure C.3-6 illustrates SO_2 removal and inlet SO_2 emissions for each test day at this site.

TABLE C.3-18. DAILY AVERAGE SO_2 REMOVAL RESULTS SPRAY DRYING PROCESS LOCATION VI[52]

Test Day[a]	SO_2 Emission Rate at Scrubber Inlet		SO_2 Emission Rate at Scrubber Outlet		Percent SO_2 Removal
	ng/J	Lb / Million Btu	ng/J	Lb / Million Btu	
1	1471	3.4	400	0.9	72.7
2	1316	3.1	390	0.9	70.3
3	1230	2.9	517	1.2	58.0
4	1613	3.8	634	1.5	60.7
5	1312	3.1	702	1.6	46.4
6	1436	3.3	568	1.3	60.4
7	1178	2.7	415	1.0	64.8
8	1118	2.6	452	1.1	59.5
9	1269	3.0	433	1.0	65.9
10	1372	3.2	638	1.5	53.5
11	1475	3.4	347	0.8	76.5
12	1449	3.4	393	0.9	72.8
13	1122	2.6	397	0.9	64.6
14	1578	3.7	460	1.1	70.9
15	1810	4.2	473	1.1	73.8
16	1557	3.6	627	1.5	59.8
17	1905	4.4	530	1.2	72.2
18	1888	4.4	418	1.0	77.9
19	1711	4.0	340	0.8	80.1
20	1608	3.7	340	0.8	78.9
21	1578	3.7	375	0.9	76.2
22	1578	3.7	339	0.8	78.5
23	1746	4.1	387	0.9	77.9
23 Day Average	1492	3.5	460	1.1	68.4

[a] 18 Hours/day minimum test time.

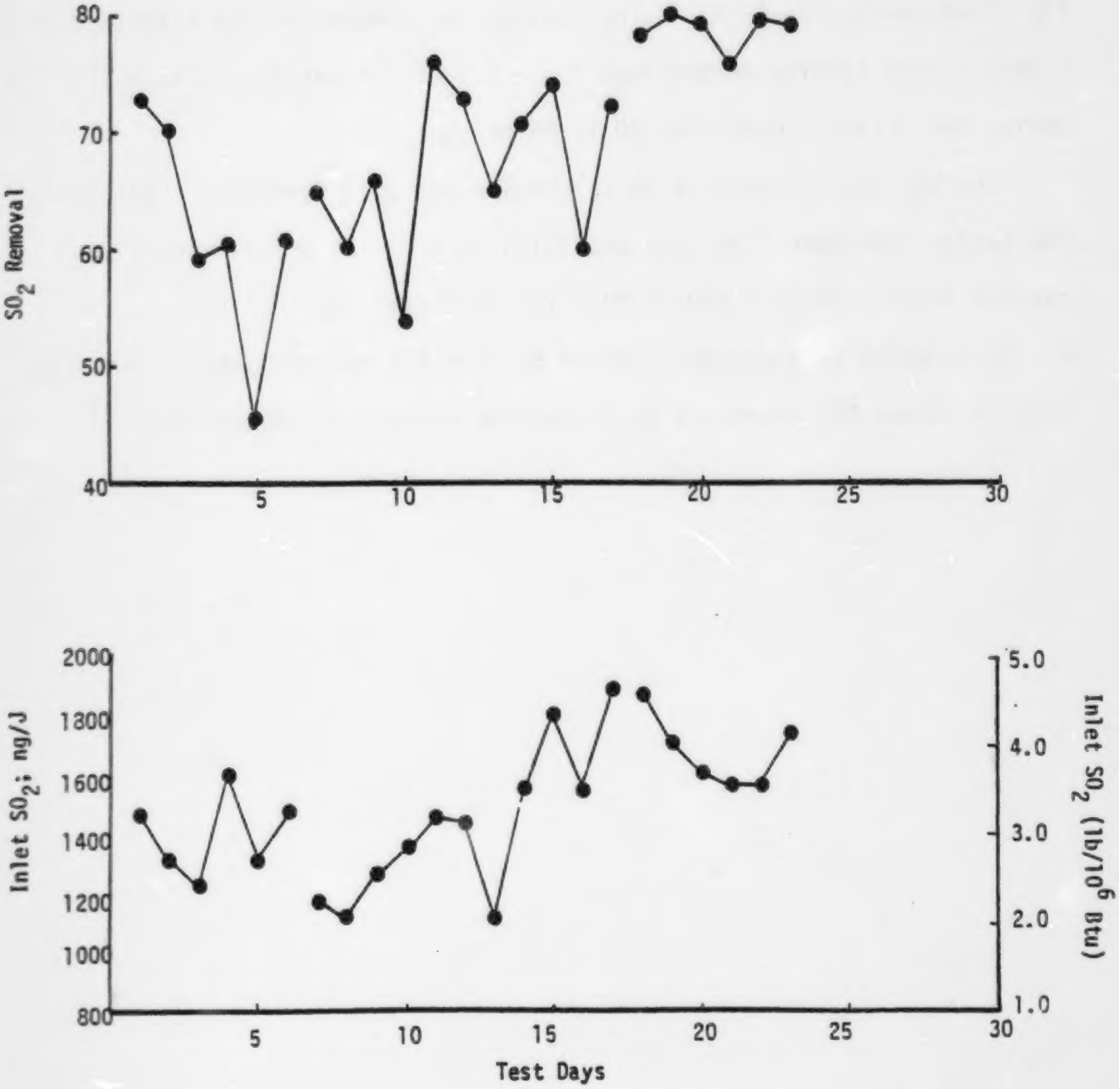

Figure C.3-6. Daily average SO_2 removal, inlet SO_2 for lime spray drying system at Location VI.

Location VII

The location monitored is a 100,000 lb steam/hr coal/limestone feed fluidized-bed boiler (FBB).* The coal sulfur content of the bituminous coal burned during testing ranged from 1.5 - 2.5 weight percent. The boiler load during the period ranged from 50 to 60 percent.

The SO_2 control used at this location was coal/limestone injection. The design limestone flow rate was 3,133 lb/hr, with actual conditions ranging from 1,500 to 4,500 lb/hr. The Ca/S ratio varied from 2 - 10 compared to a design value of 3. Low fly ash reinjection rates may have increased SO_2 emissions by decreasing sorbent residence times.[53]

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*The plant was being operated in an extended shakedown phase so that operating conditions were not always in the intended design range.

TABLE C.3-19. DAILY AVERAGE SO_2 REMOVAL RESULTS FLUIDIZED-BED COMBUSTION PROCESS LOCATION VII[53]

Test Day[a]	SO_2 Emission Rate - Inlet		SO_2 Emission Rate - Inlet		Percent SO_2 Removal
	ng/J	lb/million Btu	ng/J	lb/million Btu	
1	1030	2.4	197	0.5	80.9
2	1030	2.4	256	0.6	75.1
3	1030	2.4	220	0.5	78.7
4	1090	2.5	171	0.4	84.3
5	1030	2.4	62	0.1	94.0
6	1030	2.4	55	0.1	94.7
7	1030	2.4	47	0.1	95.4
8	1030	2.4	88	0.2	91.4
9	1120	2.6	78	0.2	93.1
10	1236	2.9	49	0.1	96.2
11	1245	2.9	178	0.4	85.7
12	1439	3.3	242	0.6	83.2
13	1477	3.4	215	0.5	85.4
14	1679	3.9	224	0.5	86.3
14 Day Average	1178	2.7	149	0.3	87.5

[a] 18 Hours/day minimum test time.

C.4 NO_x EMISSION REDUCTION DATA

This section presents emission test data for NO_x reduction by combustion modifications. The data include results of continuous monitoring tests at five sites and the results of short-term (30-minute to 2-hour) tests at a large number of sites. The short term data, which were used to construct the plots in Section 4.3.7 of this report, are presented in tabular form. Information given in these tables includes:

- test location,
- unit number (boiler designation),
- test number,
- test type,
- fuel nitrogen content,
- combustion air temperature,
- heat release rate,
- excess oxygen, and
- NO_x emissions.

More information on the boiler design and operating parameters can be found in Reference 54 and a complete description of the short-term emission testing program can be found in References 55 and 56.

Descriptions of each continuous monitoring site are provided, along with tabular and graphical presentations of daily average NO_x emissions, O_2 levels, and boiler load. Only test days with 18 or more hours of data are reported, unless noted otherwise.

Prior to commencing the monitoring programs, the NO_x monitoring systems were certified in accordance with Performance Specification 2 (PS2) and Performance Specification 3 (PS3), 40 CFR 60, Appendix B. Relative accuracy for the analyzers was tested using EPA Reference Method 7. NO_x emission rates are given in ng/J (lb/million Btu).

Location I

Low excess air (LEA) and staged combustion air (SCA) were the NO_x control technologies used at location I. Twenty-four months (681 days) of 24-hour average data was obtained for this pulverized coal-fired unit. The unit consists of two boilers, numbered 3 and 4, sharing a common stack, each with a rated capacity of 250,000 lb steam/hr. Boilers 3 and 4 averaged 177,000 and 142,000 lb steam/hr during the test period, respectively, and were fired by coal that had a nitrogen content of about 1.6 percent and a heat content of about 14,000 Btu/lb.[57] The daily results are summarized in Table C.4-1.

TABLE C.4-1. DAILY AVERAGE NO_x EMISSIONS, OXYGEN LEVELS, AND BOILER LOADS PULVERIZED COAL-FIRED - LOCATION I

(a) Month 1

	NO_x Emission Rate		O_2 Level	Boiler No. 3 Load	Boiler No. 4 Load
Test Day	ng/J	lb / million Btu	%	1000 lb steam / hr	1000 lb steam / hr
1	236.5	0.55	4.98	195	168
2	236.5	0.55	4.42	200	172
3	258.0	0.60	4.65	205	180
4	215.0	0.50	4.81	220	181
5	258.0	0.60	5.15	215	145
6	258.0	0.60	4.98	205	153
7	258.0	0.60	4.81	205	157
8	236.5	0.55	4.81	208	158
9	236.5	0.55	4.65	205	171
10	258.0	0.60	4.81	195	161
11	258.0	0.60	4.65	215	174
12	258.0	0.60	4.65	220	186
13	258.0	0.60	4.81	215	167
14	279.5	0.65	4.98	210	158
15	236.5	0.55	4.98	212	165
16	249.4	0.58	4.65	215	169
17	236.5	0.55	4.81	205	168
18	236.5	0.55	4.65	208	164
19	215.0	0.50	5.48	190	163
20	249.4	0.58	4.98	180	168
21	279.5	0.65	4.48	187	170
22	279.5	0.65	4.32	190	171
23	322.5	0.75	4.65	197	163
24	331.1	0.77	4.98	191	167
25	313.9	0.73	4.81	190	170
26	258.0	0.60	6.47	180	168
27	258.0	0.60	5.81	188	169
28	236.5	0.55	5.81	192	175
29	236.5	0.55	5.81	207	175
30	236.5	0.55	5.81	190	170
31	236.5	0.55	5.81	192	172
Monthly Average	255.4	0.59	5.02	201	168

TABLE C.4-1. (CONTINUED)

(b) Month 2

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate lb/million Btu	O_2 Level %	Boiler No. 3 Load 1000 lb steam/hr	Boiler No. 4 Load 1000 lb steam/hr
1	236.5	0.55	5.65	191	170
2	193.5	0.45	8.63	208	130
3	215.0	0.50	9.13	212	165
4	258.0	0.60	6.31	194	167
5	245.1	0.57	7.47	206	165
6	184.9	0.43	9.96	197	
7	172.0	0.40	11.79	197	
8	172.0	0.40	11.95	197	
9	150.5	0.35	11.62	210	
10	150.5	0.35	11.62	207	
11	150.5	0.35	11.95	200	
12	193.5	0.45	11.45	206	
13	193.5	0.45	11.79	187	
14	193.5	0.45	12.12	199	
15	215.0	0.50	10.79	210	163
16	236.5	0.55	10.46	105	168
17	258.0	0.60	6.97	146	177
18	279.5	0.65	6.81	160	175
19	258.0	0.60	6.47	196	180
20	236.5	0.55	6.14	213	173
21	236.5	0.55	6.14	218	175
22	236.5	0.55	5.81	220	173
23	215.0	0.50	5.64	214	182
24	215.0	0.50	5.64	228	180
25	215.0	0.50	5.64	233	184
26	236.5	0.55	6.31	203	209
27	236.5	0.55	6.47	196	199
28	236.5	0.55	6.81	214	156
29	258.0	0.60	8.47	180	108
Monthly Average	216.5	0.50	8.48	198	170

TABLE C.4-1. (CONTINUED)

(c) Month 3

Test Day	NO_x Emission Rate		O_2 Level	Boiler No. 3 Load	Boiler No. 4 Load
	ng/J	$\frac{\text{lb}}{\text{million Btu}}$	%	$\frac{\text{1000 lb steam}}{\text{hr}}$	$\frac{\text{1000 lb steam}}{\text{hr}}$
1	258.0	0.60	8.13	230	112
2	279.5	0.65	8.30	225	100
3	258.0	0.60	8.63	225	99
4	258.0	0.60	8.63	205	93
5	215.0	0.50	11.12	206	77
6	236.5	0.55	6.47	220	
7	236.5	0.55	9.96	223	188
8	258.0	0.60	6.31		
9	279.5	0.65	6.14	222	180
10	236.5	0.55	5.98	223	180
11	279.5	0.65	5.98	221	173
12	227.9	0.53	5.64	207	172
13	236.5	0.55	5.64	223	170
14	266.6	0.62	5.98	233	187
15	258.0	0.60	5.98	197	168
16	275.2	0.64	7.80	206	110
17	258.0	0.60	7.97	217	121
18	279.5	0.65	8.80	215	93
19	279.5	0.65	8.80	224	94
20	344.0	0.80	8.47	221	100
21	258.0	0.60	8.13	212	100
22	236.5	0.55	7.97	214	103
23	215.0	0.50	7.80	209	
24	215.0	0.50	7.47	203	105
25	236.5	0.55	7.97	207	105
26	245.1	0.57	8.30	199	100
27	270.9	0.63	8.47	211	92
28	262.3	0.61	8.80	224	88
29	258.0	0.60	8.47	204	93
30	215.0	0.50	8.30	197	97
31	215.0	0.50	8.30	198	103
Monthly Average	253.1	0.59	7.76	214	122

TABLE C.4-1. (CONTINUED)

(d) Month 4

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate lb/million Btu	O_2 Level %	Boiler No. 3 Load 1000 lb steam/hr	Boiler No. 4 Load 1000 lb steam/hr
1	215.0	0.50	8.30	190	105
2	236.5	0.55	8.30	186	100
3	236.5	0.55	8.80	185	100
4	258.0	0.60	6.97	188	100
5	266.6	0.62	6.81	208	147
6	215.0	0.50	7.47	215	120
7	193.5	0.45	7.64	200	120
8	279.5	0.65	9.46	132	156
9	279.5	0.65	8.47	133	174
10	227.9	0.53	9.96	206	177
11	279.5	0.65	9.96		186
12	223.6	0.52	8.30	193	200
13	227.9	0.53	7.97	186	
14	215.0	0.50	8.47	178	
15	223.6	0.52	8.47	175	
16	215.0	0.50	8.47	170	
17	215.0	0.50	8.80	156	
18	236.5	0.55	8.96	155	
19	236.5	0.55	8.63	161	
20	223.6	0.52	8.30	158	
21	215.0	0.50	8.13	164	
22	223.6	0.52	8.13	174	
23	270.9	0.63	8.13	175	
24	301.0	0.70	8.30	169	
25	245.1	0.57	8.13	171	
26	223.6	0.52	8.30	161	
27	253.7	0.59	8.30	162	
28	258.0	0.60	8.13	173	
29	270.9	0.63	7.97	180	
30	258.0	0.60	8.30	166	
31	223.6	0.52	7.47	194	
Monthly Average	240.2	0.56	8.32	175	140

TABLE C.4-1. (CONTINUED)

(e) Month 5

	NO_x Emission Rate		O_2 Level	Boiler No. 3 Load	Boiler No. 4 Load
Test Day	ng/J	$\frac{lb}{million\ Btu}$	%	$\frac{1000\ lb\ steam}{hr}$	$\frac{1000\ lb\ steam}{hr}$
1	279.5	0.65	8.13		215
2	322.5	0.75	7.64		190
3	279.5	0.65	7.47		210
4	292.4	0.68	7.14		220
5	292.4	0.68	7.97		213
6	270.9	0.63	10.29		200
7	180.6	0.42	12.45	193	
8	193.5	0.45	11.12	205	
9	180.6	0.42	11.62	193	
10	236.5	0.55	9.13	169	102
11	215.0	0.50	8.30	161	110
12	215.0	0.50	7.97	174	107
13	215.0	0.50	7.97	171	107
14	227.9	0.53	8.47	182	103
15	236.5	0.55	8.30	206	100
16	227.9	0.53	8.47	176	95
17	245.1	0.57	8.13	172	98
18	279.5	0.65	8.80	166	98
19	236.5	0.55	8.30	170	93
20	215.0	0.50	7.80	175	108
21	215.0	0.50	7.47	183	105
22	236.5	0.55	7.80	189	95
23	236.5	0.55	8.30	177	100
24	270.9	0.63	7.97	172	95
25	249.4	0.58	7.97	169	90
26	258.0	0.60	8.13	180	90
Monthly Average	242.6	0.56	8.58	179	128

TABLE C.4-1. (CONTINUED)

(f) Month 6

Test Day	NO_x Emission Rate		O_2 Level	Boiler No. 3 Load	Boiler No. 4 Load
	ng/J	$\frac{\text{lb}}{\text{million Btu}}$	%	$\frac{\text{1000 lb steam}}{\text{hr}}$	$\frac{\text{1000 lb steam}}{\text{hr}}$
1	258.0	0.60	7.97	187	98
2	245.1	0.57	9.63	187	139
3	301.0	0.70	11.29		199
4	279.5	0.65	6.31		178
5	279.5	0.65	6.81		163
6	292.4	0.68	6.81		165
7	279.5	0.65	6.47		165
8	258.0	0.60	5.81		165
9	288.1	0.67	6.64		167
10	275.2	0.64	6.31		173
11	296.7	0.69	6.81		168
12	270.9	0.63	5.98		175
13	227.9	0.53	6.14		177
14	301.0	0.70	6.64		177
15	270.9	0.63	6.64		182
16	266.6	0.62	5.81		181
17	236.5	0.55	5.64		185
18	215.0	0.50	10.99		175
19	215.0	0.50	7.80	160	116
20	266.6	0.62	7.97	197	93
21	270.9	0.63	7.97	197	100
22	292.4	0.68	8.13	199	102
23	240.8	0.56	7.97	186	98
24	163.4	0.38		192	104
25	129.0	0.30		204	94
26	236.5	0.55	7.80	201	102
Monthly Average	256.0	0.60	7.35	191	148

TABLE C.4-1. (CONTINUED)

(g) Month 7

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate lb/million Btu	O_2 Level %	Boiler No. 3 Load 1000 lb steam/hr	Boiler No. 4 Load 1000 lb steam/hr
1	215.0	0.50	7.80	167	
2	258.0	0.60	8.13	167	
3	258.0	0.60	8.63	173	
4	305.3	0.71	9.13	164	
5	236.5	0.55	6.97	167	
6	245.1	0.57	5.98	185	
7	245.1	0.57	6.97	167	
8	258.0	0.60	6.97	168	
9	245.1	0.57	7.64	162	
10	245.1	0.57	7.64	156	
11	215.0	0.50	6.31	162	
12	215.0	0.50	6.14	173	
13	215.0	0.50	5.98	179	
14	193.5	0.45	9.96	198	
15	236.5	0.55	9.13	198	66
16	240.8	0.56	8.30	163	99
17	236.5	0.55	8.47	159	102
18	215.0	0.50	7.80	183	94
19	163.4	0.38	7.14	188	109
20	193.5	0.45	7.30	167	121
21	215.0	0.50	7.47	113	159
22	184.9	0.43	7.47	139	136
23	184.9	0.43	7.30	170	106
24	215.0	0.50	7.47	168	105
25	223.6	0.52	7.80	180	99
26	245.1	0.57	8.13	173	95
27	258.0	0.60	8.13	177	97
28	258.0	0.60	8.30	171	95
Monthly Average	229.3	0.53	7.66	169	106

TABLE C.4-1. (CONTINUED)

(h) Month 8

	NO_x Emission Rate		O_2 Level	Boiler No. 3 Load	Boiler No. 4 Load
Test Day	ng/J	lb / million Btu	%	1000 lb steam / hr	1000 lb steam / hr
1	249.4	0.58	8.30	171	93
2	258.0	0.60	9.63	184	95
3	270.9	0.63	7.80	187	95
4	258.0	0.60	7.47	188	91
5	258.0	0.60	7.80	192	88
6	279.5	0.65	7.64	187	88
7	258.0	0.60	8.13	183	86
8	258.0	0.60	8.30	171	93
9	266.6	0.62	8.80	169	93
10	270.9	0.63	8.47	169	94
11	236.5	0.55	8.13	189	95
12	258.0	0.60	7.97	170	95
13	227.9	0.53	6.64	187	120
14	245.1	0.57	6.81	189	112
15	266.6	0.62	6.64	188	101
16	279.5	0.65	7.30	185	90
17	266.6	0.62	7.80	175	91
18	270.9	0.63	7.14	177	99
19	236.5	0.55	7.30	178	102
20	249.4	0.58	6.80	171	102
21	279.5	0.65	6.97	165	108
22	258.0	0.60	6.81	144	149
23	266.6	0.62	6.81	172	102
24	245.1	0.57	7.47	170	100
25	236.5	0.55	7.30	172	100
26	232.2	0.54	7.14	168	106
27	258.0	0.60	7.30	165	91
28	279.5	0.65	7.64	168	84
29	215.0	0.50	7.64	162	105
30	215.0	0.50	7.14	156	106
31	202.1	0.47	6.64	160	103
Monthly Average	253.3	0.59	7.54	175	99

TABLE C.4-1. (CONTINUED)

(i) Month 9

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate $\frac{\text{lb}}{\text{million Btu}}$	O_2 Level %	Boiler No. 3 Load $\frac{\text{1000 lb steam}}{\text{hr}}$	Boiler No. 4 Load $\frac{\text{1000 lb steam}}{\text{hr}}$
1	206.4	0.48	6.81	161	99
2	232.2	0.54	6.81	170	97
3	202.1	0.47	6.14	185	95
4	219.3	0.51	6.47	179	89
5	227.9	0.53	6.97	165	95
6	206.4	0.48	6.47	166	111
7	193.5	0.45	5.64	171	114
8	210.7	0.49	5.98	168	108
9	245.1	0.57	7.14	178	92
10	236.5	0.55	6.97	178	90
11	258.0	0.60	6.81	186	84
12	266.6	0.62	7.14	184	84
13	258.0	0.60	7.14	179	86
14	266.6	0.62	6.97	176	84
15	258.0	0.60	6.81	179	84
16	258.0	0.60	6.97	173	87
17	249.4	0.58	6.81	182	92
18	270.9	0.63	7.64	177	95
19	253.7	0.59	6.97	175	89
20	236.5	0.55	7.14	156	91
21	215.0	0.50	6.64	163	91
22	215.0	0.50	6.47	194	93
23	279.5	0.65	6.64	194	91
24	292.4	0.68	6.47	184	96
25	296.7	0.69	6.31	177	99
26	279.5	0.65	6.47	185	96
27	279.5	0.65	6.31	187	92
28	236.5	0.55	5.98	178	100
29	245.1	0.57	6.31	187	104
30	262.3	0.61	6.47	188	97
Monthly Average	245.2	0.57	6.66	178	94

TABLE C.4-1. (CONTINUED)

(j) Month 10

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate $\frac{lb}{million\ Btu}$	O_2 Level %	Boiler No. 3 Load $\frac{1000\ lb\ steam}{hr}$	Boiler No. 4 Load $\frac{1000\ lb\ steam}{hr}$
1	236.5	0.55	5.48	187	114
2	215.0	0.50	5.15	190	111
3	219.3	0.51	5.31	187	112
4	215.0	0.50	4.98	191	114
5	219.3	0.51	4.98	193	119
6	232.2	0.54	5.64	187	105
7	236.5	0.55	6.64	167	105
8	258.0	0.60	5.81	162	109
9	236.5	0.55	5.48	177	116
10	236.5	0.55	5.31	188	123
11	266.6	0.62	5.48	206	116
12	249.4	0.58	5.48	190	109
13	245.1	0.57	5.64	180	113
14	270.9	0.63	6.31	180	107
15	240.8	0.56	5.64	201	115
16	223.6	0.52		180	114
17	245.1	0.57	5.98	186	103
18	236.5	0.55	5.81	184	117
19	245.1	0.57	5.64	190	107
20	219.3	0.51	5.15	193	123
21	206.4	0.48	4.98	197	125
22	215.0	0.50	5.15	219	112
23	258.0	0.60	5.15	175	154
24	275.2	0.64	4.65	162	166
25	258.0	0.60	4.48	168	166
26	258.0	0.60	4.48	172	166
Monthly Average	239.1	0.56	5.39	185	121

TABLE C.4-1. (CONTINUED)

(k) Month 11

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate lb/million Btu	O_2 Level %	Boiler No. 3 Load 1000 lb steam/hr	Boiler No. 4 Load 1000 lb steam/hr
1	240.8	0.56	4.65	179	164
2	258.0	0.60	4.65	184	156
3	258.0	0.60	4.81	182	162
4	232.2	0.54	4.32	182	173
5	227.9	0.53	5.48	216	115
6	219.3	0.51	5.15	213	119
7	215.0	0.50	5.64	191	114
8	223.6	0.52	5.31	201	111
9	227.9	0.53	6.14	200	109
10	245.1	0.57	5.81	212	107
11	227.9	0.53	5.81	192	110
12	215.0	0.50	5.31	193	118
13	223.6	0.52	5.48	201	118
14	210.7	0.49	4.98	195	123
15	215.0	0.50	4.81	193	130
16	215.0	0.50	4.65	202	130
17	215.0	0.50	4.98	176	133
18	279.5	0.65	6.64	186	97
19	215.0	0.50	4.81	186	122
20	215.0	0.50	4.65	193	133
21	206.4	0.48	4.81	202	133
22	227.9	0.53	4.81	212	133
23	219.3	0.51	4.81	206	136
24	227.9	0.53	4.81	179	137
25	215.0	0.50	4.65	175	139
26	215.0	0.50	4.98	180	135
27	219.3	0.51	4.76	177	132
28	202.1	0.47	5.48	173	128
29	215.0	0.50	4.65	179	133
30	206.4	0.48	4.65	173	140
31	193.5	0.45	4.65	191	133
Monthly Average	223.5	0.52	5.07	191	130

TABLE C.4-1. (CONTINUED)

(1) Month 12

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate lb/million Btu	O_2 Level %	Boiler No. 3 Load 1000 lb steam/hr	Boiler No. 4 Load 1000 lb steam/hr
1	197.8	0.46	4.65	176	126
2	215.0	0.50	4.65	182	118
3	197.8	0.46	4.48	186	125
4	215.0	0.50	4.81	172	125
5	202.1	0.47	8.13		187
6	107.5	0.25	8.80		122
7	137.6	0.32	9.63		119
8	262.3	0.61	8.47		107
9	301.0	0.70	6.64		139
10	322.5	0.75	4.32		168
11	266.6	0.62	4.98		177
12	258.0	0.60	4.98		177
13	249.4	0.58	4.98		171
14	270.9	0.63	4.81		185
15	258.0	0.60	4.65		189
16	193.5	0.45	8.80		189
17	202.1	0.47	6.64	211	210
18	215.0	0.50	4.48	204	189
19	258.0	0.60	4.32	190	202
20	219.3	0.51	4.32	199	210
21	219.3	0.51	4.15	212	194
22	245.1	0.57	3.98		231
23	262.3	0.61	3.82	235	235
24	227.9	0.53	3.98	220	228
25	253.7	0.59	4.32	201	220
26	253.7	0.59	3.82	199	173
27	262.3	0.61	4.32	172	130
28	223.6	0.52	4.98	181	163
29	236.5	0.55	7.97	198	
30	258.0	0.60	4.32	182	163
Monthly Average	233.1	0.54	5.44	195	171

TABLE C.4-1. (CONTINUED)

(m) Month 13

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate $\frac{\text{lb}}{\text{million Btu}}$	O_2 Level %	Boiler No. 3 Load $\frac{\text{1000 lb steam}}{\text{hr}}$	Boiler No. 4 Load $\frac{\text{1000 lb steam}}{\text{hr}}$
1	245.1	0.57	4.81	170	176
2	236.5	0.55	6.64	175	101
3	223.6	0.52	6.14	182	109
4	206.4	0.48	4.81	179	124
5	227.9	0.53	6.47	160	125
6	227.9	0.53	5.81	168	128
7	227.9	0.53	5.64	189	125
8	202.1	0.47	5.15	204	128
9	206.4	0.48	5.31	201	132
10	253.7	0.59	5.48	197	134
11	279.5	0.65	6.64	197	117
12	223.6	0.52	7.30	133	120
13	292.4	0.68	7.30	126	119
14	283.8	0.66	7.30	139	117
15	258.0	0.60	6.47	145	127
16	266.6	0.62	6.31	155	123
Monthly Average	241.3	0.56	6.10	170	125

TABLE C.4-1. (CONTINUED)

(n) Month 14

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate $\frac{lb}{million\ Btu}$	O_2 Level %	Boiler No. 3 Load $\frac{1000\ lb\ steam}{hr}$	Boiler No. 4 Load $\frac{1000\ lb\ steam}{hr}$
1	219.3	0.51	6.81	151	120
2	236.5	0.55	5.81	165	125
3	215.0	0.50	5.81	161	132
4	227.9	0.53	5.31	159	129
5	232.2	0.54	5.31	179	127
6	223.6	0.52	5.81	168	125
7	236.5	0.55	5.98	169	125
8	215.0	0.50	5.98	170	127
9	227.9	0.53	5.81	164	120
10	223.6	0.52	5.98	154	123
11	236.5	0.55	7.30	153	119
12	227.9	0.53	7.47	163	143
13	236.5	0.55	6.97	148	125
14	206.4	0.48	6.47	145	125
15	202.1	0.47	6.31	146	133
16	215.0	0.50	6.47	148	132
17	215.0	0.50	6.31	150	130
18	219.3	0.51	6.47	131	129
19	245.1	0.57	6.97	158	138
20	215.0	0.50	6.64	160	134
21	236.5	0.55	7.47	161	121
22	219.3	0.51	6.47	152	133
23	215.0	0.50	6.64	157	130
24	249.4	0.58	5.81	164	129
25	215.0	0.50	6.31	151	129
26	240.8	0.56	6.31	161	130
27	223.6	0.52	6.14	164	127
28	227.9	0.53	6.31	170	124
29	245.1	0.57	7.14	188	129
30	219.3	0.51	6.47	179	137
Monthly Average	225.6	0.52	6.37	160	128

TABLE C.4-1. (CONTINUED)

(o) Month 15

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate $\frac{\text{lb}}{\text{million Btu}}$	O_2 Level %	Boiler No. 3 Load $\frac{\text{1000 lb steam}}{\text{hr}}$	Boiler No. 4 Load $\frac{\text{1000 lb steam}}{\text{hr}}$
1	189.2	0.44	6.47	170	135
2	202.1	0.47	6.14	170	131
3	206.4	0.48	6.64	169	135
4	210.7	0.49	7.30	174	127
5	223.6	0.52	7.30	169	121
6	215.0	0.50	7.14	173	128
7	215.0	0.50	6.97	173	117
8	227.9	0.53	6.64	166	129
9	215.0	0.50	6.81	166	111
10	206.4	0.48	6.64	167	123
11	215.0	0.50	6.97	168	124
12	219.3	0.51	7.30	169	118
13	223.6	0.52	6.81	161	123
14	215.0	0.50	6.81	168	121
15	215.0	0.50	7.14	176	121
16	206.4	0.48	6.97	170	114
17	215.0	0.50	7.30	170	123
18	219.3	0.51	6.97	169	129
19	223.6	0.52	7.97	170	107
20	223.6	0.52	7.47	171	122
21	223.6	0.52	7.64	189	125
22	215.0	0.50	6.64	188	125
23	236.5	0.55	8.30	172	129
24	240.8	0.56	6.97	167	119
25	258.0	0.60	6.64	198	129
26	245.1	0.57	6.97	194	132
27	262.3	0.61	6.31	211	128
28	262.3	0.61	6.47	189	123
29	227.9	0.53	6.47	173	126
30	236.5	0.55	6.64	170	125
31	236.5	0.55	6.97	169	118
Monthly Average	223.6	0.52	6.96	174	124

TABLE C.4-1. (CONTINUED)

(p) Month 16

	NO_x Emission Rate		O_2 Level	Boiler No. 3 Load	Boiler No. 4 Load
Test Day	ng/J	$\frac{\text{lb}}{\text{million Btu}}$	%	$\frac{\text{1000 lb steam}}{\text{hr}}$	$\frac{\text{1000 lb steam}}{\text{hr}}$
1	258.0	0.60	6.97	188	128
2	258.0	0.60	5.81	169	132
3	249.4	0.58	5.81	169	128
4	258.0	0.60	6.31	175	129
5	339.7	0.79	6.64	167	103
6	301.0	0.70	8.13	169	105
7	279.5	0.65	7.80	205	154
8	288.1	0.67	8.30	151	163
9	215.0	0.50	9.96	121	133
10	236.5	0.55	7.80	181	131
11	172.0	0.40	6.81	177	129
12	279.5	0.65	6.64	159	173
13	288.1	0.67	6.31	155	169
14	266.6	0.62	5.98	153	164
15	279.5	0.65	6.31	150	155
16	270.9	0.63	6.14	151	165
17	262.3	0.61	5.98	165	163
18	270.9	0.63	6.47	178	141
19	279.5	0.65	5.81	166	157
20	279.5	0.65	5.81	115	163
21	301.0	0.70	5.81	160	165
22	313.9	0.73	5.81	155	164
23	296.7	0.69	5.81	148	164
24	313.9	0.73	5.81	144	162
25	305.3	0.71	5.81	150	152
26	258.0	0.60	6.64	168	127
27	245.1	0.57	6.81	174	132
28	335.4	0.78	6.14	145	151
29	335.4	0.78	6.31	157	151
30	270.9	0.63	5.81	166	172
31	258.0	0.60	5.98	177	165
Monthly Average	276.3	0.64	6.53	162	148

TABLE C.4-1. (CONTINUED)

(q) Month 17

	NO_x Emission Rate		O_2 Level	Boiler No. 3 Load	Boiler No. 4 Load
Test Day	ng/J	$\frac{\text{lb}}{\text{million Btu}}$	%	$\frac{\text{1000 lb steam}}{\text{hr}}$	$\frac{\text{1000 lb steam}}{\text{hr}}$
1	245.1	0.57	6.14	174	168
2	215.0	0.50	5.98	169	160
3	236.5	0.55	6.31	146	176
4	223.6	0.52	5.64	142	179
5	262.3	0.61	5.48	191	152
6	236.5	0.55	5.64	200	150
7	249.4	0.58	5.48	202	154
8	258.0	0.60	5.48	189	175
9	245.1	0.57	4.98	187	179
10	245.1	0.57	5.48	169	182
11	279.5	0.65	5.48	178	179
12	288.1	0.67	5.98	166	181
13	258.0	0.60	5.48	171	195
14	262.3	0.61	5.81	180	174
15	249.4	0.58	5.81	176	166
16	206.4	0.48	5.48	171	161
17	206.4	0.48	5.31	167	174
18	236.5	0.55	5.31	167	185
19	210.7	0.49	5.31	170	169
20	215.0	0.50	5.15	175	159
21	202.1	0.47	5.48	165	163
22	206.4	0.48	5.64	165	169
23	215.0	0.50	5.64	164	167
24	184.9	0.43	5.64	162	168
25	193.5	0.45	5.64	160	164
26	206.4	0.48	5.64	168	154
Monthly Average	232.2	0.54	5.59	172	169

TABLE C.4-1. (CONTINUED)

(r) Month 18

	NO_x Emission Rate		O_2 Level	Boiler No. 3 Load	Boiler No. 4 Load
Test Day	ng/J	lb/million Btu	%	1000 lb steam/hr	1000 lb steam/hr
1	223.6	0.52	5.48	200	
2	215.0	0.50	7.97	193	
3	210.7	0.49	7.97	169	169
4	206.4	0.48	5.48	181	153
5	258.0	0.60	6.47	177	160
6	215.0	0.50	5.48	165	172
7	223.6	0.52	5.48	168	169
8	227.9	0.53	5.64	167	165
9	206.4	0.48	4.98	167	160
10	184.9	0.43	4.81	176	168
11	180.6	0.42	4.98	174	157
12	236.5	0.55	4.98	166	161
13	236.5	0.55	5.15	171	150
14	202.1	0.47	5.15	183	150
Monthly Average	216.2	0.50	5.72	176	161

TABLE C.4-1. (CONTINUED)

(s) Month 19

Test Day	NO_x Emission Rate		O_2 Level	Boiler No. 3 Load	Boiler No. 4 Load
	ng/J	lb / million Btu	%	1000 lb steam / hr	1000 lb steam / hr
1	193.5	0.45	5.48	176	123
2	159.1	0.37	5.81	184	134
3	172.0	0.40	5.64	172	122
4	172.0	0.40	6.31	181	132
5	163.4	0.38	9.46	114	
6	223.6	0.52	13.61	88	
7	197.8	0.46	15.77	100	89
8	210.7	0.49	9.46	177	89
9	176.3	0.41	6.64	175	111
10	180.6	0.42	6.81	158	115
11	180.6	0.42	6.64	172	107
12	176.3	0.41	6.14	179	111
13	215.0	0.50	4.98	181	129
14	210.7	0.49	5.15	167	157
15	184.9	0.43	5.15	164	173
16	184.9	0.43	4.98	168	175
17	184.9	0.43	4.98	167	155
18	202.1	0.47	5.64	165	184
19	172.0	0.40	5.31	166	172
20	193.5	0.45	5.64	171	157
21	215.0	0.50	5.81	171	159
22	193.5	0.45	5.81	168	159
23	180.6	0.42	4.98	165	178
24	202.1	0.47	4.81	169	179
25	206.4	0.48	5.31	170	170
26	210.7	0.49	5.15	168	175
27	206.4	0.48	5.50	170	177
28	227.9	0.53	5.00	142	162
29	258.0	0.60	5.00	135	158
30	258.0	0.60	5.16	133	156
Monthly Average	197.1	0.46	6.40	161	147

TABLE C.4-1. (CONTINUED)

(t) Month 20

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate lb/million Btu	O_2 Level %	Boiler No. 3 Load 1000 lb steam/hr	Boiler No. 4 Load 1000 lb steam/hr
1	266.6	0.62	5.48	139	157
2	292.4	0.68	5.31	160	156
3	266.6	0.62	5.64	165	155
4	258.0	0.60	5.64	156	150
5	227.9	0.53	5.15	165	157
6	197.8	0.46	5.81	177	122
7	184.9	0.43	6.31	174	123
8	227.9	0.53		165	103
9	189.2	0.44		170	114
10	180.6	0.42		177	113
11	197.8	0.46	6.64	172	116
12	202.1	0.47	5.98	166	128
13	163.4	0.38	5.31	166	139
14	163.4	0.38	5.98	163	122
15	163.4	0.38	6.14	169	125
16	163.4	0.38	5.81	171	123
17	172.0	0.40	6.47	172	121
18	215.0	0.50	6.47	166	131
19	193.5	0.45	5.81	154	134
20	206.4	0.48	6.31	165	121
21	163.4	0.38		162	117
22	159.1	0.37		158	120
23	150.5	0.35	6.31	147	130
24	141.9	0.33	6.47	167	119
25	133.3	0.31	5.64	164	127
26	141.9	0.33	5.31	182	123
27	141.9	0.33	4.98	200	137
28	150.5	0.35	4.65	193	134
29	150.5	0.35	4.98	191	135
30	141.9	0.33	4.98	194	141
31	172.0	0.40	4.81	167	197
Monthly Average	186.4	0.43	5.71	169	132

TABLE C.4-1. (CONTINUED)

(u) Month 21

	NO_x Emission Rate		O_2 Level	Boiler No. 3 Load	Boiler No. 4 Load
Test Day	ng/J	$\frac{\text{lb}}{\text{million Btu}}$	%	$\frac{\text{1000 lb steam}}{\text{hr}}$	$\frac{\text{1000 lb steam}}{\text{hr}}$
1	176.3	0.41	4.65	166	197
2	184.9	0.43	4.98	165	180
3	202.1	0.47	4.98	182	160
4	193.5	0.45	4.81	168	159
5	206.4	0.48	4.98	152	140
6	206.4	0.48	4.65	173	179
7	219.3	0.51	4.65	171	176
8	206.4	0.48	4.81	166	166
9	189.2	0.44	4.81	156	170
10	184.9	0.43	4.81	174	192
11	193.5	0.45	4.32	187	186
12	202.1	0.47	4.65	167	166
13	219.3	0.51	4.98	166	163
14	223.6	0.52	4.65	148	174
15	236.5	0.55	4.81	162	153
16	215.0	0.50	4.81	150	160
17	215.0	0.50	4.81	153	165
18	215.0	0.50	4.81	160	153
19	227.9	0.53	5.15	150	170
20	206.4	0.48	5.15	175	173
21	193.5	0.45	4.65	175	167
22	202.1	0.47	4.65	173	184
23	215.0	0.50	4.81	177	157
24	236.5	0.55	4.81	178	150
25	227.9	0.53	4.65	177	164
26	223.6	0.52	4.65	171	159
27	236.5	0.55	4.98	175	160
28	266.6	0.62	4.81	167	175
29	258.0	0.60	4.81	166	178
30	236.5	0.55	4.81	163	167
Monthly Average	214.0	0.50	4.80	167	168

TABLE C.4-1. (CONTINUED)

(v) Month 22

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate lb/million Btu	O_2 Level %	Boiler No. 3 Load 1000 lb steam/hr	Boiler No. 4 Load 1000 lb steam/hr
1	258.0	0.60	4.98	152	161
2	258.0	0.60	5.15	150	164
3	258.0	0.60	4.81	151	165
4	249.4	0.58	4.81	147	166
5	227.9	0.53	4.48	152	168
6	215.0	0.50	4.32	168	182
7	215.0	0.50	4.32	171	175
8	184.9	0.43	4.48	169	179
9	172.0	0.40	4.32	168	192
10	159.1	0.37	4.15	170	199
11	184.9	0.43	4.15	178	199
12	172.0	0.40	4.32	179	196
13	163.4	0.38	4.15	176	183
14	159.1	0.37	4.48	185	181
15	159.1	0.37	4.15	193	187
16	159.1	0.37	4.32	196	186
17	176.3	0.41	4.32	183	189
18	159.1	0.37	4.32	174	193
19	150.5	0.35	3.82	174	197
20	141.9	0.33	4.15	169	183
21	159.1	0.37	4.15	166	182
22	172.0	0.40	4.32	171	179
23	159.1	0.37	4.15	183	189
24	159.1	0.37	4.32	167	217
25	159.1	0.37	4.15	170	201
26	159.1	0.37	3.98	177	197
27	172.0	0.40	4.15	170	199
28	193.5	0.45	6.14	183	201
29	189.2	0.44	4.32	189	177
30	193.5	0.45	5.48	177	136
31	163.4	0.38	5.64	166	138
Monthly Average	183.9	0.43	4.48	172	183

TABLE C.4-1. (CONTINUED)

(w) Month 23

	NO_x Emission Rate		O_2 Level	Boiler No. 3 Load	Boiler No. 4 Load
Test Day	ng/J	$\frac{lb}{million\ Btu}$	%	$\frac{1000\ lb\ steam}{hr}$	$\frac{1000\ lb\ steam}{hr}$
1	137.6	0.32	4.98	165	153
2	172.0	0.40	4.65	159	169
3	176.3	0.41	4.65	156	169
4	176.3	0.41	6.14	156	165
5	180.6	0.42	4.48	172	173
6	184.9	0.43	4.48	175	177
7	184.9	0.43	4.32	176	176
8	184.9	0.43	4.15	173	184
9	172.0	0.40	4.32	172	186
10	180.6	0.42	4.81	171	172
11	184.9	0.43		178	168
12	184.9	0.43		165	174
13	184.9	0.43		164	168
14	184.9	0.43		171	182
15	189.2	0.44		149	130
16	215.0	0.50		84	
17	129.0	0.30		101	
18	172.0	0.40	9.13	99	
19	236.5	0.55	7.47	133	
20	236.5	0.55	7.97	106	
21	116.1	0.27	9.79	89	
22	107.5	0.25	12.45	112	
23	120.4	0.28	10.29	182	10
24	172.0	0.40	6.14	167	162
25	163.4	0.38	4.98	174	133
26	133.3	0.31	5.15	167	136
27	141.9	0.33	5.31	163	125
28	141.9	0.33	5.31	181	123
29	141.9	0.33	5.31	176	124
30	141.9	0.33	5.31	161	125
31	141.9	0.33	6.64	165	122
Monthly Average	167.4	0.39	6.18	154	150

TABLE C.4-1. (CONTINUED)

(x) Month 24

Test Day	NO_x Emission Rate ng/J	NO_x Emission Rate $\frac{\text{lb}}{\text{million Btu}}$	O_2 Level %	Boiler No. 3 Load $\frac{\text{1000 lb steam}}{\text{hr}}$	Boiler No. 4 Load $\frac{\text{1000 lb steam}}{\text{hr}}$
1	150.5	0.35	6.31	174	121
2	159.1	0.37	6.31	188	124
3	167.7	0.39	5.81	166	147
4	210.7	0.49	5.15	167	139
5	215.0	0.50	5.48	166	145
6	206.4	0.48	5.15	163	149
7	193.5	0.45	5.81	169	121
8	172.0	0.40	5.48	173	141
9	193.5	0.45	5.15	161	145
10	172.0	0.40	7.47	175	139
11	159.1	0.37	7.47		210
12	150.5	0.35	7.89		225
13	202.1	0.47	6.97		208
14	193.5	0.45	4.98		203
15	202.1	0.47	4.98		195
16	206.4	0.48	4.98		192
17	163.4	0.38	8.30		200
18	146.2	0.34	7.89	104	183
19	172.0	0.40	5.98	116	159
20	163.4	0.38	6.14	160	118
21	172.0	0.40	5.48	173	122
22	167.7	0.39	6.14	182	120
23	172.0	0.40	5.81	162	133
24	163.4	0.38	5.81	133	168
25	176.3	0.41	5.48	140	183
26	193.5	0.45	4.98	182	190
27	167.7	0.39	4.81	186	178
28	206.4	0.48	4.81	181	181
29	202.1	0.47	4.81	202	181
30	189.2	0.44	4.81	181	182
Monthly Average	180.3	0.42	5.89	165	163
24 Month Average	225.9	0.53	6.43	177	142

Location II

The coal-fired spreader stoker boiler at Location II employed low excess air (LEA) as the NO_x control technology. The boiler currently has a 100,000 steam/hr capacity. During the test period the actual maximum capacity was 90,000 lb steam/hr. However, for the purposes of showing percent of boiler load, the rated capacity of 100,000 lb steam/hr was used. During the test period, midwestern coal containing 1.27 to 1.42 weight percent nitrogen and about 12,000 Btu/lb heat content was burned.

Continuous monitoring data was obtained for 30 days. The 24-hour data is presented in Tables C.4-2 through C.4-4. During the test period the average boiler load was 70,000 lb steam/hr, with hourly readings ranging from 50,000 to 85,000 lb steam/hr.[59] Figure C.4-1 shows the emissions, boiler load, and oxygen level for each test day.

TABLE C.4-2. DAILY AVERAGE NO_x EMISSIONS SPREADER STOKER-LOCATION II[59]

	NO_x Emission Rate	
Test Day[a]	ng/J	$\frac{\text{lb}}{\text{Million Btu}}$
1	174.8	0.41
2	167.7	0.39
3	181.7	0.42
4	189.1	0.44
5	185.1	0.43
6	184.4	0.43
7	187.4	0.44
8	181.9	0.42
9	167.7	0.39
10	177.7	0.41
11	182.6	0.43
12	180.4	0.42
13	169.9	0.40
14	171.1	0.40
15	161.9	0.38
16	159.3	0.37
17	153.9	0.36
18	161.8	0.38
19	165.4	0.39
20	168.4	0.39
21	180.1	0.42
22	161.8	0.38
23	160.1	0.37
24	161.1	0.38
25	159.1	0.37
26	159.9	0.37
27	156.2	0.36
28	162.4	0.38
29	164.0	0.38
30	164.3	0.38
30 Day Average	170.0	0.40

[a] 18 Hours/day minimum test time.

TABLE C.4-3. DAILY SUMMARY OF HOURLY O_2 LEVELS SPREADER STOKER - LOCATION II[59]

Test Day[a]	Minimum Hourly O_2 Level (%)	24-Hour Average O_2 Level (%)	Maximum Hourly O_2 Level (%)
1	6.43	7.05	7.83
2	6.43	6.88	7.50
3	6.80	7.58	9.15
4	6.68	7.69	8.68
5	6.43	7.53	8.98
6	7.00	7.82	10.00
7	6.45	7.76	9.83
8	6.55	7.44	8.30
9	6.73	7.40	8.58
10	6.68	7.59	9.08
11	6.93	7.83	8.73
12	7.08	7.60	8.37
13	6.28	7.11	7.75
14	5.45	7.34	9.10
15	5.73	6.74	7.93
16	4.78	6.90	7.95
17	5.18	6.52	8.00
18	4.68	6.58	7.75
19	5.93	6.82	7.70
20	6.20	7.21	8.28
21	6.75	7.43	8.70
22	6.28	7.21	8.35
23	6.18	7.10	8.35
24	5.70	6.94	8.05
25	5.90	6.31	7.58
26	5.78	6.58	7.93
27	4.48	6.02	7.50
28	5.98	6.87	8.05
29	6.38	7.84	9.58
30	6.65	7.90	9.25

[a] 18 Hours/day minimum test time.

TABLE C.4-4. DAILY SUMMARY OF HOURLY BOILER LOADS SPREADER STOKER - LOCATION II[59]

Test Day[a]	Minimum Hourly Boiler Load (MW)	24-Hour Average Boiler Load (MW)	Maximum Hourly Boiler Load (MW)
1	20.5	20.5	20.5
2	20.5	20.5	20.5
3	19.9	20.6	22.0
4	18.8	21.0	23.4
5	20.5	20.7	22.3
6	16.1	20.1	21.7
7	20.5	20.9	22.9
8	19.3	21.4	23.4
9	20.2	21.2	22.9
10	16.1	20.1	22.0
11	19.0	20.4	20.8
12	19.9	20.6	21.4
13	19.9	21.0	22.3
14	16.1	20.5	22.9
15	17.6	20.5	22.9
16	17.6	21.1	23.1
17	20.5	21.6	24.0
18	19.0	22.0	24.9
19	19.6	21.1	23.1
20	19.9	20.8	22.0
21	18.5	20.6	22.0
22	17.0	19.7	21.4
23	16.1	18.1	19.6
24	17.0	19.3	22.9
25	19.0	21.5	22.9
26	17.6	20.2	22.9
27	20.5	21.2	22.9
28	19.6	20.6	22.0
29	14.6	17.8	22.0
30	16.4	17.9	20.5

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[a] 18 Hours/day minimum test time.

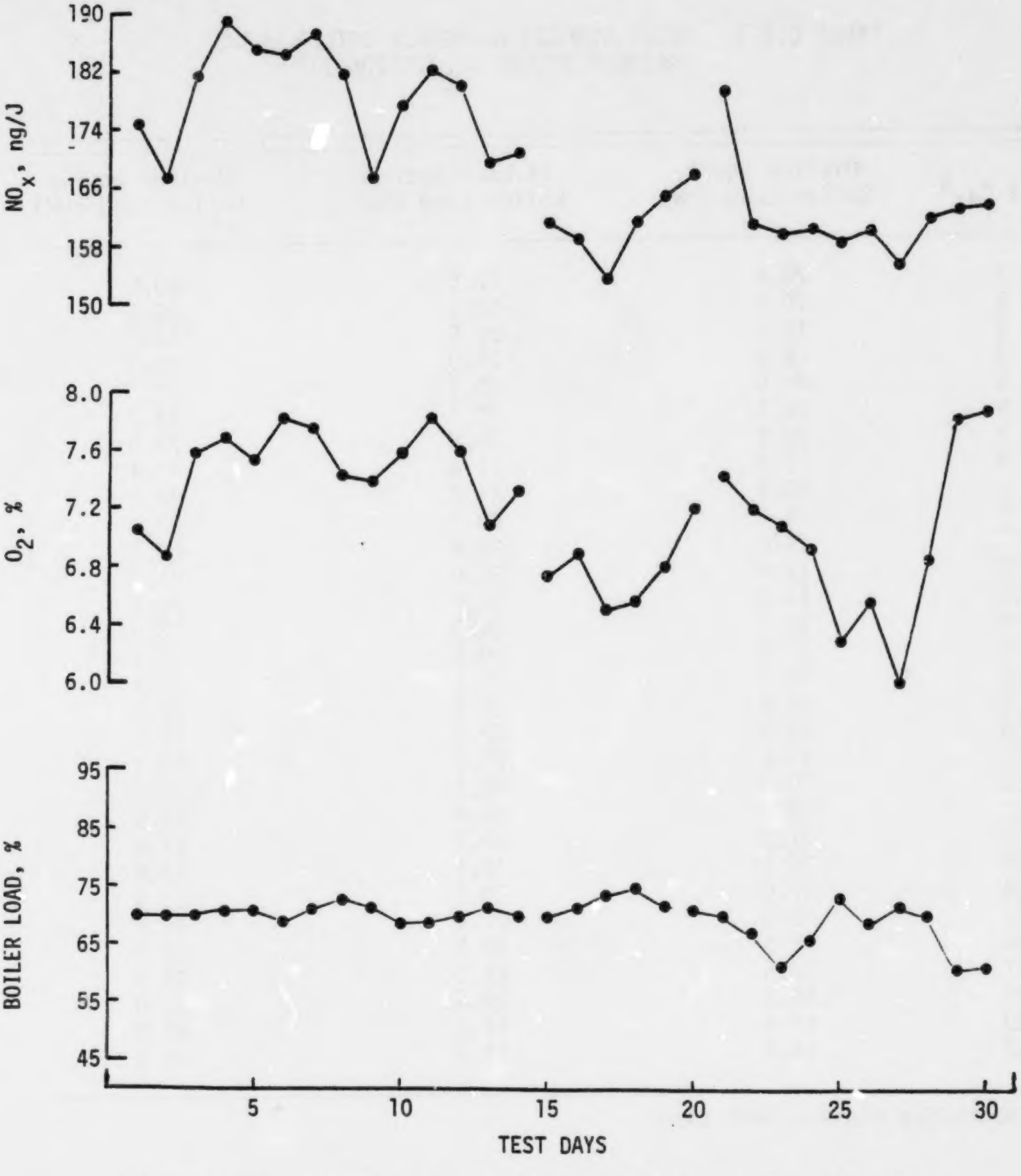

Figure C.4-1. Continuous monitoring data for LEA combustion modification on a spreader stoker coal-fired boiler at Location II.

Location III

The 160,000 lb steam/hr coal-fired spreader stoker boiler at Location III used LEA as the NO_x control technology. However, this technique was only used during non-holiday, weekday dayshifts. The hours where LEA was not used were low demand periods, so that increased excess air operation coincided with low steam demand. The capacity rating was based on coal with a heat content of 12,000 Btu/lb. The daily results are given in Tables C.4-5 through C.4-7.

During the 18-day test period, a western coal having a heat content of about 8,500 Btu/lb and a nitrogen content of 0.76 to 0.80 weight percent was burned. The hourly average boiler load ranged from 59,000 to 122,000 lb steam/hr while averaging 97,000 lb steam/hr during the test period.[60] The 8-hour averaged emission rates, boiler loads, and oxygen levels are illustrated in Figure C.4-2.

TABLE C.4-5. 8-HOUR AVERAGE NO_x EMISSIONS SPREADER STOKER - LOCATION III[60]

	NO_x Emission Rate	
Test Day[a]	ng/J	$\frac{lb}{Million\ Btu}$
1	203.9	0.47
2	190.3	0.44
3	222.3	0.52
4	200.5	0.47
5	209.0	0.49
6	230.9	0.54
7	189.6	0.44
8	214.9	0.50
9	206.0	0.48
10	216.1	0.50
11	198.9	0.46
12	208.3	0.48
13	213.6	0.50
14	194.4	0.45
15	208.1	0.48
16	214.1	0.50
17	211.5	0.49
18	202.9	0.47
18 Day Average	207.5	0.48

[a] 6 Hours LEA operation/day minimum test time.

TABLE C.4-6. DAILY (8-Hour Average) SUMMARY OF HOURLY O_2 LEVELS SPREADER STOKER - LOCATION III[60]

Test Day[a]	Minimum Hourly O_2 Level (%)	8-Hour Average O_2 Level (%)	Maximum Hourly O_2 Level (%)
1	8.50	8.93	9.30
2	8.30	9.04	9.50
3	9.20	9.40	9.50
4	8.80	8.98	9.30
5	8.10	8.45	8.80
6	7.90	8.29	8.80
7	7.60	8.11	8.40
8	8.40	8.55	8.80
9	8.80	9.08	9.50
10	8.40	8.69	9.30
11	7.70	8.31	8.90
12	6.90	7.55	8.40
13	8.10	8.45	8.90
14	6.90	7.24	7.80
15	6.70	7.54	8.90
16	7.20	7.80	8.40
17	8.80	8.88	9.00
18	8.50	8.86	9.30

[a] 6 Hours LEA operation/day minimum test time.

TABLE C.4-7. DAILY (8-Hour Average) SUMMARY OF HOURLY BOILER LOADS SPREADER STOKER - LOCATION III[60]

Test Day[a]	Minimum Hourly Boiler Load (MW)	8-Hour Average Boiler Load (MW)	Maximum Hourly Boiler Load (MW)
1	17.3	19.4	22.0
2	24.3	25.6	27.8
3	20.2	24.2	26.1
4	24.0	25.7	27.2
5	26.4	28.1	29.9
6	27.8	30.9	33.4
7	28.1	30.1	33.1
8	26.1	28.3	29.3
9	24.0	25.9	27.8
10	26.1	28.1	29.3
11	26.1	29.8	32.8
12	30.2	32.8	34.6
13	27.0	29.7	30.8
14	30.8	32.5	34.0
15	29.3	34.0	35.7
16	27.2	30.9	32.5
17	26.7	27.6	28.4
18	24.3	26.9	28.4

[a] 6 Hours LEA operation/day minimum test time.

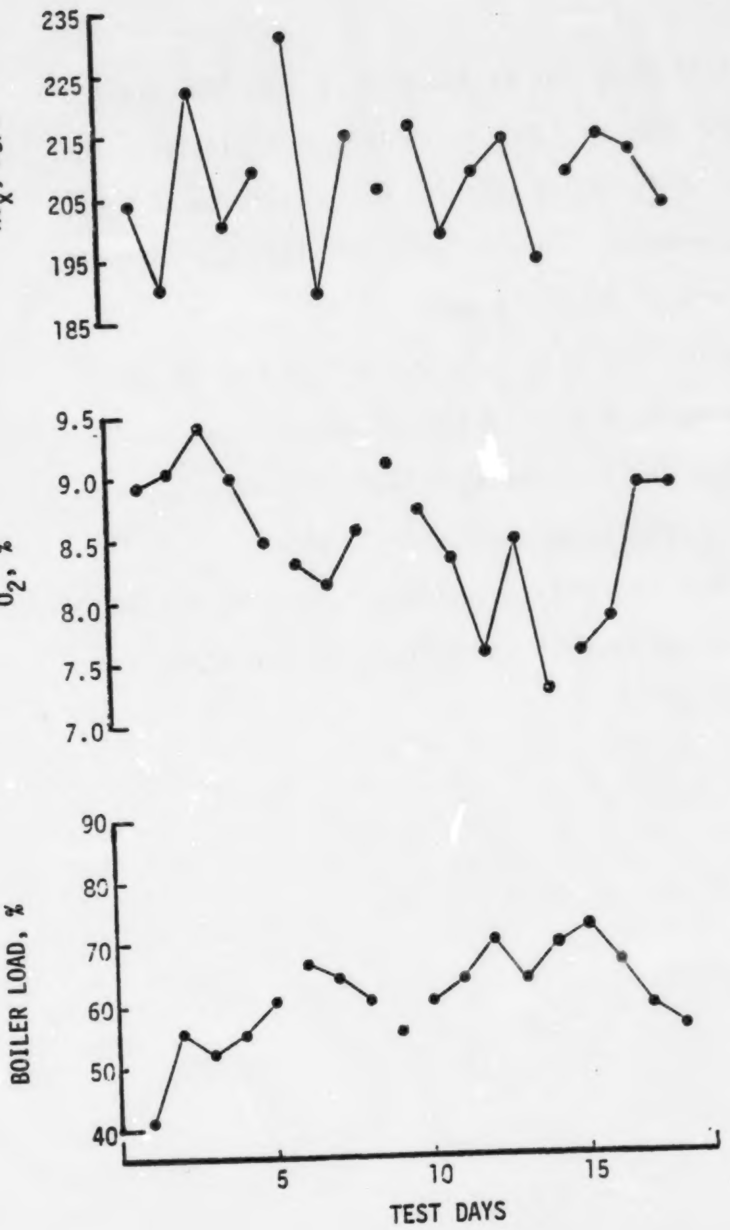

Figure C.4-2. Continuous monitoring data (8-hour average) for LEA combustion modification on a spreader stoker coal-fired boiler at Location III.

Location IV

The residual oil-fired boiler at location IV used low excess air (LEA) and staged combustion air (SCA) as control technologies. The boiler has a capacity of 79,000 lb steam/hr which falls to 50,000 lb steam/hr during SCA operation. During the 29-day test period, high demand precluded the use of SCA on 16 days.

The fuel used during the test period had a 0.24 to 0.28 weight percent nitrogen content and a heat content of about 15,500 Btu/lb. During that time, the boiler load averaged 57,000 lb steam/hr, with hourly averages ranging from 36,000 to 73,000 lb steam/hr. Tables C.4-8 through C.4-10 show the daily emissions, O_2 levels, and boiler load.[61] Figure C.4-3 shows the daily emissions, boiler loads, and oxygen levels for each day.

TABLE C.4-8. DAILY AVERAGE NO_x EMISSIONS RESIDUAL OIL-FIRED - LOCATION IV[61]

Test Day[a]	NO_x Emission Rate ng/J	NO_x Emission Rate lb/Million Btu	NO_x Control Technique[b]
1	129.3	0.30	L
2	121.0	0.28	L
3	149.9	0.35	L
4	121.2	0.28	L
5	111.4	0.26	S
6	95.8	0.22	S
7	89.5	0.21	S
8	87.7	0.20	S
9	100.4	0.23	S
10	106.9	0.25	S
11	100.2	0.23	S
12	82.7	0.19	S
13	120.1	0.28	L
14	117.9	0.27	L
15	108.8	0.25	S
16	90.4	0.21	S
17	87.7	0.20	S
18	106.5	0.25	L
19	113.9	0.27	L
20	125.5	0.29	L
21	127.0	0.30	L
22	119.7	0.28	L
23	127.6	0.30	L
24	128.4	0.30	L
25	119.9	0.28	L
26	126.3	0.29	L
27	120.0	0.28	L
28	103.3	0.24	S
29	104.5	0.24	S
29 Day Average	111.8	0.26	

[a] 18 Hours/day minimum test time.

[b] L = LEA only.
S = LEA/SCA.

TABLE C.4-9. DAILY SUMMARY OF HOURLY O_2 LEVELS, RESIDUAL OIL-FIRED - LOCATION IV[61]

Test Day[a]	Minimum Hourly O_2 Level (%)	24-Hour Average O_2 Level (%)	Maximum Hourly O_2 Level (%)	NO_x Control Technique[b]
1	7.00	8.50	9.18	L
2	7.60	8.06	8.58	L
3	6.73	8.07	9.33	L
4	7.20	7.72	8.38	L
5	7.10	7.57	8.13	S
6	7.00	7.48	7.90	S
7	7.40	7.61	7.90	S
8	7.10	7.60	7.98	S
9	7.63	7.91	8.30	S
10	8.10	8.46	8.78	S
11	7.50	7.96	8.65	S
12	7.30	7.82	8.10	S
13	8.20	9.98	10.23	L
14	10.20	10.79	11.95	L
15	7.70	9.16	11.10	S
16	6.98	7.25	7.55	S
17	6.70	7.09	7.40	S
18	6.40	6.78	7.20	L
19	6.18	6.64	7.30	L
20	6.05	6.31	6.75	L
21	6.25	7.03	10.60	L
22	7.18	10.13	11.40	L
23	7.03	8.05	10.58	L
24	7.40	8.79	11.98	L
25	6.90	7.25	7.60	L
26	7.30	7.42	7.65	L
27	6.90	7.69	8.68	L
28	7.33	7.94	8.73	S
29	7.65	9.16	12.60	S

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[a] 18 Hours/day minimum test time.

[b] L = LEA only.
S = LEA/SCA.

TABLE C.4-10. DAILY SUMMARY OF HOURLY BOILER LOADS RESIDUAL OIL-FIRED - LOCATION IV[61]

Test Day[a]	Minimum Hourly Boiler Load (MW)	24-Hour Average Boiler Load (MW)	Maximum Hourly Boiler Load (MW)	NO_x Control Technique[b]
1	14.5	15.4	18.2	L
2	14.4	15.3	19.1	L
3	15.6	16.5	18.5	L
4	15.4	16.5	18.5	L
5	16.4	16.7	17.9	S
6	16.4	16.6	16.8	S
7	16.4	16.6	16.9	S
8	16.2	16.5	16.8	S
9	16.1	16.4	17.7	S
10	16.1	16.3	16.4	S
11	16.2	16.5	16.7	S
12	16.4	16.6	16.7	S
13	13.5	13.9	14.1	L
14	13.3	13.6	15.4	L
15	13.3	15.8	17.0	S
16	15.9	16.4	18.2	S
17	16.1	16.8	19.5	S
18	16.2	17.4	19.9	L
19	19.7	20.6	21.1	L
20	18.9	20.7	21.5	L
21	14.8	19.3	20.1	L
22	10.7	14.0	18.2	L
23	16.2	17.4	19.5	L
24	18.5	19.2	19.9	L
25	18.7	19.0	19.5	L
26	18.0	19.4	19.9	L
27	15.9	17.1	18.8	L
28	15.9	16.8	17.5	S
29	16.1	16.7	17.5	S

[a] 18 Hours/day minimum test time.

[b] L = LEA only.
S = LEA/SCA.

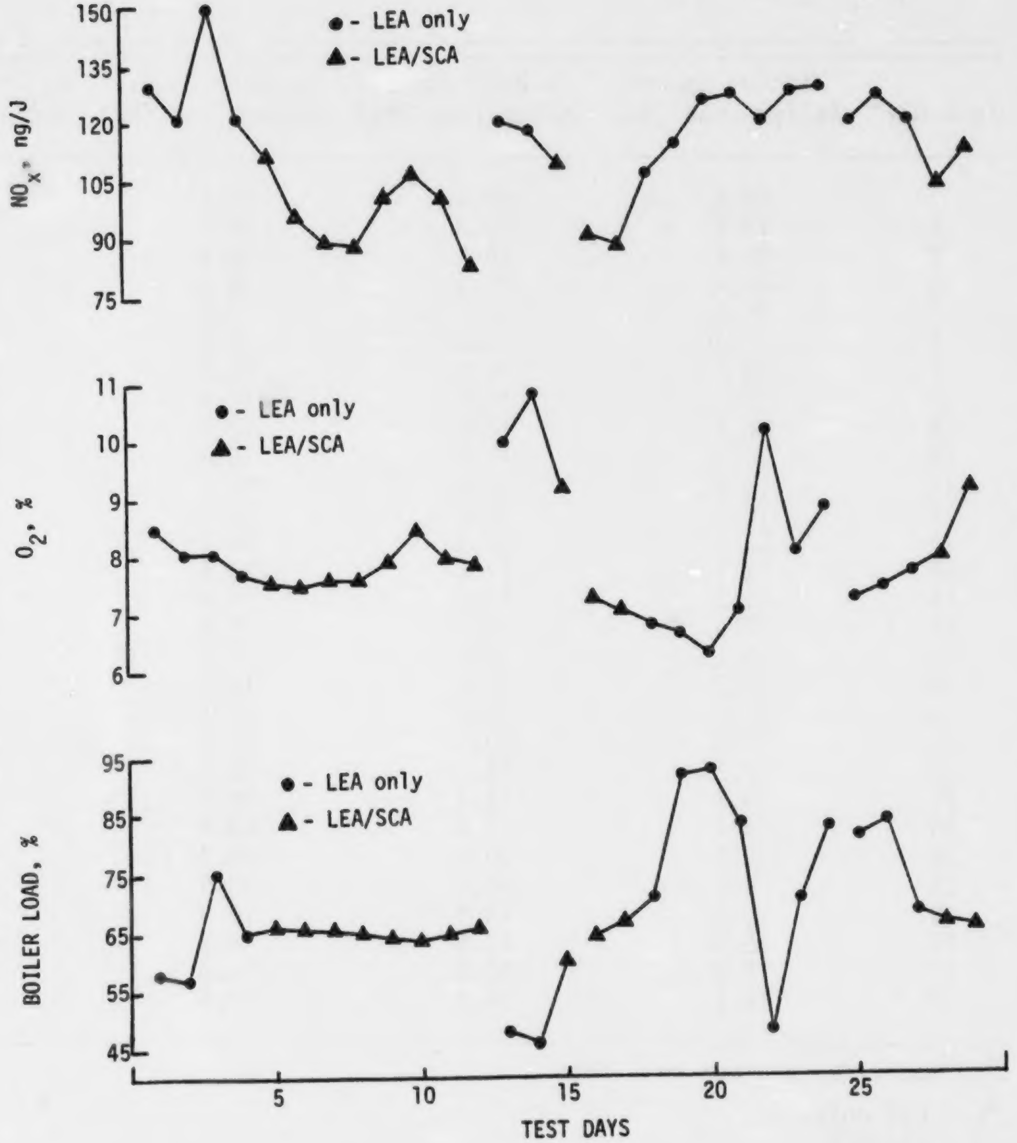

Figure C.4-3. Continuous monitoring data for LEA/SCA combustion modification on a residual oil-fired boiler at Location IV.

Location V

Location V is a 6,900 lb steam/hr capacity natural gas-fired boiler. The boiler is only in operation approximately 19 hours a day during non-holiday weekdays. Thus, only 21 days of data were gathered during the 36-day test period. The daily emissions data are presented in Tables C.4-11 to C.4-12. Low excess air (LEA) was the NO_x control technique used during operation.[62] The 19-hour average emission rates and oxygen levels are shown in Figure C.4-4.

TABLE C.4-11. 19-HOUR AVERAGE NO_x EMISSIONS NATURAL GAS-FIRED - LOCATION V[62]

Test Day[a]	NO_x Emission Rate ng/J	NO_x Emission Rate lb/Million Btu
1	30.2	0.07
2	27.9	0.07
3	28.9	0.07
4	29.0	0.07
5	28.2	0.07
6	28.8	0.07
7	28.7	0.07
8	29.6	0.07
9	29.6	0.07
10	28.1	0.07
11	28.7	0.07
12	29.0	0.07
13	30.9	0.07
14	31.4	0.07
15	30.9	0.07
16	26.7	0.06
17	29.7	0.07
18	30.4	0.07
19	31.8	0.07
20	33.5	0.08
21	33.1	0.08
21 Day Average	29.8	0.07

[a] 15 Hours/day minimum test time.

TABLE C.4-12. DAILY (19-Hour Average) SUMMARY OF HOURLY O_2 LEVELS NATURAL GAS-FIRED - LOCATION V62

Test Day[a]	Minimum Hourly O_2 Level (%)	19-Hour Average O_2 Level (%)	Maximum Hourly O_2 Level (%)
1	6.70	8.34	10.43
2	6.35	7.28	10.10
3	5.78	6.41	8.30
4	5.68	6.81	8.68
5	4.80	7.42	10.08
6	6.20	7.91	10.33
7	4.80	7.50	10.23
8	5.03	7.70	9.45
9	5.40	6.95	9.00
10	6.40	7.34	8.93
11	4.68	6.59	9.08
12	5.48	7.62	9.43
13	4.00	5.58	6.55
14	4.80	5.62	9.83
15	7.00	9.56	12.87
16	4.90	7.64	11.20
17	3.88	5.79	6.90
18	4.60	5.94	6.90
19	4.75	6.19	7.15
20	2.60	8.49	10.53
21	6.93	9.67	11.13

[a] 15 Hours/day minimum test time.

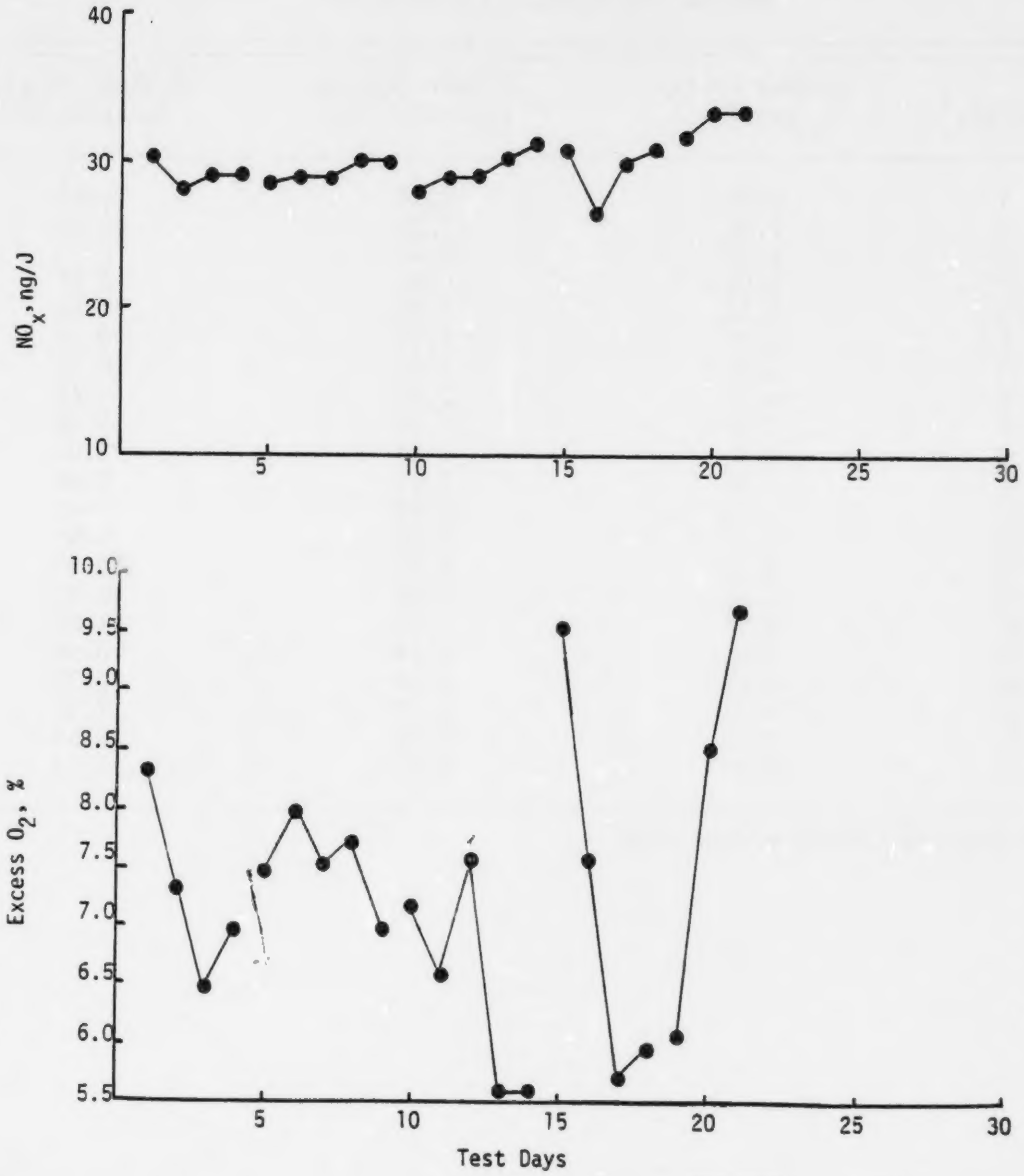

Figure C.4-5. Continuous NO_x emission data for a small natural gas boiler at Location V.

Location VI

The location monitored is a 100,000 lb steam/hr coal/limestone feed fluidized-bed boiler (FBB). The plant was not always operated in the intended design range since the test period covered an extended shakedown period. The coal nitrogen content during testing was approximately 1.5 percent. Daily boiler loads during the period ranged from 50 to 60 percent.

Low excess air was the only NO_x control technology used. However, due to shakedown operating conditions, high excess air conditions were recorded during the test. Daily O_2 levels ranged from 8.8 to 12.3 percent.

TABLE C.4-13. DAILY AVERAGE EMISSION RATES, O_2 LEVELS, AND BOILER LOADS LOCATION VI - FLUIDIZED BED BOILER[53]

Test Dat[a]	NO_x Emission Rate		O_2 Level	Boiler Load
	ng/J	lb/million Btu	%	1000 lb steam/hr
1	313	0.7	12.1	52
2	282	0.7	11.8	50
3	237	0.6	9.2	53
4	226	0.5	8.8	56
5	256	0.6	10.4	55
6	251	0.6	9.5	57
7	342	0.8	11.2	54
8	441	1.0	12.3	53
9	323	0.8	10.7	56
10	288	0.7	10.0	59
11	250	0.6	8.9	61
12	262	0.6	8.8	62
13	289	0.7	10.2	54
14	267	0.6	11.4	48
15	255	0.6	10.3	56
16	218	0.5	8.8	57
16 day Average	281	0.7	10.3	55

[a] 18 Hours/day minimum test time.

Key to Symbols for Short-Term Data Tables

LN	Location number as given in Reference 54
UN	Boiler designation (unit number) - Reference 54
TN	Test number - Reference 54
TT	Test type
FN	Fuel nitrogen content (lb/10^6 Btu)
CT	Combustion air temperature (°F)
HR	Heat release rate (10^3 Btu/hr ft^2)
EO	Excess oxygen in flue gas (%)
NE	NO_x emissions (ppm at 3% O_2 dry)*
BA	Baseline air (boiler operating at at least 80% capacity)
LA	Low excess air
NA	"Normal" excess air - Reference 54
HA	High excess air
LL	Low load
HL	High load
SC	Staged combustion
BO	Burner-out-of-service

* 75 ppm NO_x at 3% O_2 dry is approximately 0.1 lb/10^6 Btu.

TABLE C.4-14: SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-14: UNSTAGED COMBUSTION IN COAL-FIRED SPREADER STOKER BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	FUEL NITROGEN (LB/MILLION BTU)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
11	1	18.01	390	1.10	8.0	60.0	49.27945
11	1	18.02	389	1.10	7.7	60.0	55.07703
11	1	18.03	373	1.10	7.0	60.0	60.70493
11	1	18.04	379	1.10	5.5	60.0	59.71510
11	1	18.05	367	1.10	6.0	60.0	59.13534
11	1	18.06	338	1.10	4.9	60.0	65.28643
11	1	18.07	373	1.10	5.8	60.0	63.19364
11	1	18.08	379	1.10	6.5	60.0	61.45437
11	1	18.09	417	1.10	6.9	60.0	63.77340
11	1	18.10	460	1.10	7.5	60.0	60.87461
11	1	18.11	353	1.10	5.3	60.0	63.77340
11	1	18.12	464	1.10	9.7	60.0	37.68428
11	1	18.13	474	1.10	11.6	60.0	28.98791
11	1	18.14	431	1.10	9.0	60.0	43.48187
11	1	18.15	359	1.10	6.5	60.0	43.48187
11	1	18.16	374	1.10	8.1	60.0	42.32235
11	1	18.17	404	1.10	8.4	60.0	41.74259
11	1	18.18	337	1.10	6.5	60.0	41.74259
11	1	18.19	429	1.10	7.4	60.0	70.15074
11	1	18.20	423	1.10	7.2	60.0	76.31067
11	1	18.21	385	1.10	6.5	60.0	63.77340
14	1	27.01	550	1.01	10.3	350.0	90.90493
14	1	27.02	540	1.01	10.1	350.0	90.98129
14	1	27.03	487	1.01	9.5	350.0	90.98129
14	1	27.04	470	1.01	8.9	350.0	92.11856
14	1	27.05	571	1.01	10.8	350.0	89.90047
14	1	27.06	509	1.01	11.8	350.0	67.74914
14	1	27.07	519	1.01	13.4	350.0	52.16368
14	1	27.08	610	1.01	15.8	350.0	36.78567
14	1	27.09	564	1.01	10.2	350.0	91.42421
14	1	27.10	564	1.01	9.0	350.0	116.54961
14	1	27.11	449	1.01	9.0	350.0	90.98129
14	1	27.12	475	1.01	11.8	350.0	89.88163

TABLE C.4-14 (Continued): SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-14:

UNSTAGED COMBUSTION IN COAL-FIRED SPREADER STOKER BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	FUEL NITROGEN (LB/MILLION BTU)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
14	4	28.01	540	1.35	10.6	60.0	75.80146
14	4	28.02	542	1.35	10.8	60.0	78.82650
14	4	28.03	631	1.35	12.5	60.0	73.94167
14	4	28.04	540	1.35	11.3	60.0	72.80000
14	4	28.05	427	1.35	10.1	60.0	73.28533
14	4	28.06	358	1.35	8.9	60.0	70.16867
14	4	28.07	595	1.35	15.5	60.0	37.60526
14	4	28.08	461	1.35	13.0	60.0	47.90417
14	4	28.09	494	1.35	11.9	60.0	62.61125
14	4	28.10	571	1.35	10.6	60.0	87.56250
14	4	28.11	598	1.35	10.8	60.0	95.64228
14	4	28.12	538	1.35	10.6	60.0	78.24667
21	2	19.01	476	1.05	9.4	60.0	39.12598
21	2	19.02	431	1.05	8.3	60.0	43.03858
21	2	19.03	396	1.05	6.4	60.0	46.95591
21	2	19.04	355	1.05	5.5	60.0	48.91732
21	2	19.05	471	1.05	7.4	60.0	50.52726
21	2	19.06	464	1.05	8.0	60.0	38.64684
21	2	19.07	462	1.05	9.0	60.0	31.69700
21	2	19.08	448	1.05	7.3	60.0	40.10413
21	2	19.09	330	1.05	5.8	60.0	39.12992
21	3	20.01	506	1.04	7.6	60.0	37.91450
21	3	20.02	497	1.04	8.2	60.0	38.55030
21	3	20.03	526	1.04	9.0	60.0	37.91830
21	3	20.04	359	1.04	5.5	60.0	38.67340
21	3	20.05	435	1.04	6.6	60.0	39.29720
21	3	20.06	463	1.04	7.8	60.0	39.81420
21	3	20.07	414	1.04	5.9	60.0	47.40130
21	3	20.08	506	1.04	9.3	60.0	32.86250
21	3	20.09	489	1.04	9.9	60.0	28.17470
21	3	20.10	389	1.04	5.9	60.0	38.29850

TABLE C.4-15: SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-15: STAGED COMBUSTION IN COAL-FIRED SPREADER STOKER BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	TEST TYPE	NOX EMISSIONS (PPM)	FUEL NITROGEN (LB/MILLION BTU)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (F)	HEAT RELEASE RATE (1000 BTU/HR FT FT)
30	8	134.01	NA	323	1.19	6.2	200	52.98497
30	8	134.02	BA	320	1.19	6.2	200	51.85721
30	8	134.03	NA	298	1.19	6.1	200	52.23784
30	8	134.05	NA	312	1.19	6.2	197	52.12456
30	8	134.06	NA	274	1.19	6.2	198	51.79772
30	8	135.01	LA	237	1.19	5.4	202	51.55305
30	8	135.02	LA	233	1.19	4.7	205	51.28136
30	8	135.03	LA	216	1.19	5.2	205	51.53349
30	8	136.01	SC	295	1.19	6.3	200	52.57480
30	8	136.02	SC	319	1.19	6.6	200	52.73066
30	8	136.03	SC	237	1.19	6.1	200	51.61704
30	8	139.01	NA	312	1.19	10.3	180	30.08392
30	8	139.02	LA	263	1.19	9.0	190	29.94493
30	8	139.03	LA	195	1.19	7.4	200	29.57517
30	8	139.04	LL	351	1.19	10.3	190	31.22586
30	8	139.05	NA	360	1.19	10.0	180	31.46543
30	8	139.06	NA	371	1.19	9.4	180	31.85787
30	8	139.07	SC	342	1.19	9.6	180	32.36538
30	8	139.08	NA	327	1.19	9.3	180	31.86616
30	8	139.09	NA	330	1.19	9.4	180	31.94905
30	8	139.10	SC	269	1.19	7.7	182	31.85655

TABLE C.4-16: SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-16: COMBUSTION IN MASS FED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	TEST TYPE	NOX EMISSIONS (PPM)	FUEL NITROGEN (LB/MILLION BTU)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
15	32.1	16.01	NA	331	1.21	7.5	80.0	39.21404
15	32.1	16.02	LA	297	1.21	6.0	82.0	39.21404
15	32.1	16.03	NA	255	1.21	7.0	80.0	41.45068
15	32.1	16.04	NA	272	1.21	8.7	75.0	33.37365
15	32.1	16.05	LL	186	1.21	9.4	75.0	25.37135
15	32.1	16.06	LL	226	1.21	13.1	74.0	16.93607
15	32.1	16.07	NA	294	1.21	7.1	71.0	40.42851
15	32.1	16.08	HL	319	1.21	6.1	74.0	51.91466
15	32.1	16.09	LA	179	1.21	6.7	75.0	37.72030
15	32.1	16.10	LA	192	1.21	4.9	75.0	36.39975
15	32.1	16.11	HA	264	1.21	7.0	79.0	38.20086
15	32.1	16.12	BA	266	1.21	6.6	79.0	39.28186
15	32.1	16.13	HA	273	1.21	8.2	78.0	38.55853
15	32.1	16.14	NA	233	1.21	7.9	78.0	34.62516
15	32.1	16.15	NA	207	1.21	9.0	80.0	26.18978
15	32.1	16.16	LL	235	1.21	12.3	78.0	17.16034
35	6.0	165.01	BA	164	0.79	9.5	230.0	39.35569
35	6.0	165.02	NA	171	0.79	9.5	217.0	39.99223
35	6.0	165.03	NA	170	0.79	9.6	210.0	39.19221
35	6.0	166.01	LA	122	0.79	9.0	225.0	38.78377
35	6.0	166.02	LA	130	0.79	8.3	235.0	35.31303
35	6.0	166.03	LA	140	0.79	8.8	220.0	39.79412
35	6.0	166.04	LA	126	0.79	8.7	220.0	38.87876
35	6.0	166.05	HA	154	0.79	10.9	220.0	40.95380
35	6.0	166.06	LA	137	0.79	8.8	217.0	38.77224
35	6.0	166.07	LA	157	0.79	8.4	218.0	40.34154
35	6.0	166.08	LA	158	0.79	8.2	230.0	41.60272
35	6.0	167.01	NA	147	0.79	9.4	230.0	34.67047
35	6.0	167.02	HL	155	0.79	8.3	212.0	44.98808
35	6.0	167.03	LL	193	0.79	11.3	235.0	23.46960
35	6.0	167.04	LL	235	0.79	12.5	240.0	20.10301
35	6.0	168.05	NA	164	0.79	9.4	235.0	39.53084
35	6.0	168.01	SC	158	0.79	9.9	220.0	36.09587
35	6.0	168.02	SC	150	0.79	8.5	225.0	40.40546
35	6.0	168.03	SC	166	0.79	9.0	230.0	38.45467
35	6.0	168.04	SC	174	0.79	10.3	230.0	35.89736

TABLE C.4-17: SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-18:
UNSTAGED COMBUSTION IN RESIDUAL OIL-FIRED BOILERS WITH AIR PREHEAT[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	FUEL NITROGEN (LB/MILLION BTU)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
18	3	21.01	291	0.14	7.0	420.0	75.36035
18	3	21.02	235	0.14	7.0	390.0	55.57826
18	3	21.03	220	0.14	7.7	370.0	43.33220
18	3	21.04	235	0.14	8.7	358.0	34.45101
18	3	21.05	273	0.14	5.0	435.0	93.25843
18	3	21.06	253	0.14	6.3	410.0	76.04682
18	3	21.07	206	0.14	5.3	410.0	75.14150
18	3	21.08	225	0.14	6.1	415.0	74.02312
18	3	21.09	314	0.14	7.6	418.0	75.37544
18	4	22.01	242	0.14	6.8	548.0	84.44150
18	4	22.02	281	0.14	7.8	525.0	72.74960
18	4	22.03	305	0.14	8.1	505.0	58.45950
18	4	22.04	321	0.14	8.2	480.0	46.78165
18	4	22.05	245	0.14	7.1	550.0	85.74060
18	4	22.06	237	0.14	7.1	550.0	82.18745
18	4	22.07	237	0.14	7.2	542.0	77.96941
18	4	22.08	236	0.14	6.5	542.0	77.96941
18	4	22.09	233	0.14	6.0	542.0	77.96941
18	4	22.10	257	0.14	7.8	542.0	77.96941
18	4	22.11	270	0.14	8.6	590.0	76.64690
29	5	[illegible].01	294	0.17	5.0	395.0	75.78997
29	5	117.01	266	0.17	4.1	392.0	76.18802
29	5	117.02	246	0.17	3.1	388.0	76.81768
29	5	117.03	285	0.17	5.6	400.0	75.55837
29	5	119.01	248	0.17	5.5	360.0	43.75209
29	5	119.02	258	0.17	5.2	360.0	44.07128
29	5	121.01	254	0.17	5.4	350.0	45.32591
29	5	121.02	295	0.17	5.4	350.0	44.06685
29	5	121.03	263	0.17	5.5	350.0	43.75209
37	2	176.02	195	0.16	4.3	227.0	74.74873
37	2	176.03	191	0.16	4.6	225.0	73.80689
37	2	176.04	195	0.16	4.3	229.0	75.72910
37	2	176.05	198	0.16	4.6	231.0	75.93206
37	2	176.06	190	0.16	4.4	231.0	77.12368
37	2	176.07	189	0.16	4.6	234.0	75.00511
37	2	179.01	179	0.16	3.8	231.0	76.86716
37	2	179.02	196	0.16	5.2	233.0	75.65392
37	2	179.03	201	0.16	5.7	230.0	74.92948
37	2	179.04	174	0.16	4.0	234.0	74.76388

TABLE C.4-18: SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-18: UNSTAGED COMBUSTION IN RESIDUAL OIL-FIRED BOILERS WITHOUT AIR PREHEAT[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	FUEL NITROGEN (LB/MILLION BTU)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
16	2	10.01	180	0.15	3.7	60.0	61.33572
16	2	10.02	189	0.15	4.7	60.0	66.39590
16	2	10.03	197	0.15	4.0	60.0	64.55157
16	2	10.04	187	0.15	3.6	60.0	62.94477
16	2	10.05	210	0.15	5.1	60.0	63.30294
16	2	10.06	229	0.15	7.6	60.0	41.19005
16	2	10.07	266	0.15	13.3	60.0	31.84744
16	2	10.09	205	0.15	5.2	60.0	61.32338
18	2	9.01	246	0.14	7.4	60.0	53.04549
18	2	9.02	218	0.14	8.7	60.0	34.70892
18	2	9.03	192	0.14	8.6	60.0	30.27800
18	2	9.04	242	0.14	6.8	60.0	58.32301
18	2	9.05	259	0.14	7.8	60.0	53.14450
18	2	9.06	216	0.14	7.0	60.0	52.99017
18	2	9.07	285	0.14	8.5	60.0	52.99017
18	2	9.08	236	0.14	7.4	60.0	51.69414
18	2	9.09	256	0.14	7.5	60.0	53.88262
19	1	1.01	423	0.24	4.4	60.0	50.90107
19	1	1.02	338	0.24	2.3	60.0	52.66695
19	1	1.03	276	0.24	1.6	60.0	50.91139
19	1	1.04	338	0.24	2.7	60.0	50.90107
19	1	1.05	391	0.24	5.0	60.0	50.90107
19	1	1.06	336	0.24	3.6	60.0	49.84795
19	1	1.07	375	0.24	6.4	60.0	34.05796
19	1	1.08	420	0.24	11.0	60.0	20.01547
19	1	1.09	373	0.24	4.2	60.0	44.94246
19	1	1.10	390	0.24	4.2	60.0	49.11102
19	1	1.11	341	0.24	2.3	60.0	50.88045
19	1	1.12	357	0.24	3.6	60.0	51.47383
19	1	1.13	385	0.24	4.9	60.0	50.51931
19	1	1.14	444	0.24	5.8	60.0	48.04889
19	1	2.01	402	0.24	6.6	60.0	50.44972
19	1	2.02	388	0.24	5.7	60.0	50.44461
19	1	2.03	339	0.24	4.3	60.0	52.22083
19	1	2.04	286	0.24	2.8	60.0	51.51034
19	1	2.05	339	0.24	4.4	60.0	52.22083
19	1	2.06	303	0.24	4.7	60.0	51.10847

TABLE C.4-18 (Continued): SHORT-TERM NO$_x$ EMISSION DATA FOR FIGURE 4.3-18: UNSTAGED COMBUSTION IN RESIDUAL OIL-FIRED BOILERS WITHOUT AIR PREHEAT[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	FUEL NITROGEN (LB/MILLION BTU)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000' BTU/HR·FT·FT)
19	2	195.01	169	0.07	3.1	105.0	50.32110
19	2	195.02	177	0.07	3.2	108.0	50.32620
19	2	195.03	185	0.07	3.6	96.0	49.92118
19	2	195.04	171	0.07	3.1	92.0	50.32620
19	2	195.05	163	0.07	2.7	122.0	49.95154
19	2	195.06	202	0.07	3.1	98.0	49.60725
19	2	195.07	220	0.07	3.1	93.0	48.52392
19	2	195.08	184	0.07	2.7	96.0	49.60725
19	2	195.09	197	0.07	3.0	90.0	50.32620
19	2	195.10	149	0.07	3.1	112.0	48.52883
19	2	196.01	163	0.07	1.6	103.0	49.69887
19	2	196.02	124	0.07	0.9	101.0	50.42418
19	2	196.03	178	0.07	3.5	100.0	50.04371
19	2	196.04	180	0.07	4.6	100.0	49.70390
19	2	200.01	148	0.07	2.9	102.0	50.56361
19	2	200.02	165	0.07	3.3	97.0	50.93770
19	2	200.03	162	0.07	2.9	109.0	50.94285
19	2	200.04	165	0.07	2.9	108.0	52.02395
19	2	200.05	153	0.07	2.9	101.0	51.66015
19	2	200.06	177	0.07	3.1	108.0	52.39306
19	2	200.07	131	0.07	2.9	103.0	51.29634
19	2	201.01	138	0.07	2.3	105.0	50.32110
19	2	201.02	145	0.07	3.6	104.0	50.68567
19	2	201.03	140	0.07	2.7	104.0	50.32620
19	2	201.04	147	0.07	2.9	103.0	50.32620
19	2	203.01	136	0.07	3.0	105.0	50.33639
19	2	203.02	120	0.07	2.3	105.0	50.34149
19	2	203.03	122	0.07	2.2	105.0	51.05031
19	2	203.04	143	0.07	3.0	106.0	52.12356
19	2	203.05	141	0.07	3.0	105.0	51.05031
20	4	8.01	305	0.20	5.8	60.0	91.87270
20	4	8.02	328	0.20	5.2	60.0	113.28082
20	4	8.03	305	0.20	7.2	60.0	75.54795
20	4	8.04	277	0.20	6.5	60.0	60.80688
20	4	8.05	310	0.20	5.7	60.0	95.11122
20	4	8.06	272	0.20	4.7	60.0	91.67346
20	4	8.07	277	0.20	4.0	60.0	95.13064

TABLE C.4-18 (Continued): SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-18: UNSTAGED COMBUSTION IN RESIDUAL OIL-FIRED BOILERS WITHOUT AIR PREHEAT[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	FUEL NITROGEN (LB/MILLION BTU)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
20	4	8.08	290	0.20	5.4	60.0	95.32175
20	4	170.01	259	0.16	3.5	93.0	120.19462
20	4	170.02	251	0.16	3.5	93.0	121.77915
20	4	170.03	264	0.16	3.3	90.0	114.94754
20	4	170.04	227	0.16	3.3	91.0	118.08887
20	4	170.05	260	0.16	3.7	91.5	118.08887
20	4	171.01	264	0.16	5.5	91.0	58.69739
20	4	171.02	286	0.16	6.3	94.0	70.14066
20	4	171.03	256	0.16	5.0	91.0	73.29769
20	4	171.04	240	0.16	4.2	93.0	89.78968
20	4	171.05	263	0.16	4.5	92.0	91.84764
20	4	171.06	262	0.16	4.5	90.0	93.16760
20	4	171.08	275	0.16	4.6	95.0	94.13615
20	4	171.09	249	0.16	4.2	93.0	95.71266
20	4	171.10	262	0.16	3.8	95.0	11[illegible].17708
20	4	172.01	261	0.16	3.7	93.0	113.93175
20	4	172.02	255	0.16	2.7	92.0	115.47169
20	4	172.03	270	0.16	3.8	92.0	114.56247
20	4	175.01	267	0.16	3.4	93.0	114.56247
20	4	175.02	258	0.16	2.8	93.0	114.56247
20	4	175.03	240	0.16	2.0	93.0	114.56247
20	4	175.04	258	0.16	3.4	89.0	116.38092
20	4	175.06	240	0.16	2.8	91.0	115.47169
27	1	111.01	458	0.42	9.3	60.0	140.04567
27	1	111.03	521	0.42	4.5	60.0	131.86122
27	1	111.04	560	0.42	7.3	60.0	135.15775
27	1	111.05	536	0.42	8.2	60.0	135.30864
27	1	111.06	537	0.42	6.2	60.0	136.80602
27	1	111.07	508	0.42	6.0	60.0	138.45428
27	1	111.08	401	0.42	5.9	60.0	135.08916
27	1	111.09	499	0.42	8.9	60.0	98.88588
27	1	111.10	439	0.42	9.1	60.0	90.59018
27	1	111.12	592	0.42	11.0	60.0	57.67757
27	1	111.13	598	0.42	11.1	60.0	32.94188
27	1	111.14	554	0.42	11.0	60.0	46.17953

TABLE C.4-19: SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-19: : STAGED COMBUSTION IN RESIDUAL OIL-FIRED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	TEST TYPE	NOX EMISSIONS (PPM)	FUEL NITROGEN (LB/MILLION BTU)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (F)	HEAT RELEASE RATE (1000 BTU/HR FT FT)
7	3	6.19	BO	220	0.17	8.1	240	74.43871
7	3	6.36	BO	174	0.17	6.0	242	100.67064
18	2	9.10	BO	175	0.14	8.2	60	44.75086
18	3	21.13	BO	220	0.14	6.0	410	71.37009
18	3	21.15	BO	221	0.14	6.3	410	70.43101
18	3	21.16	BO	217	0.14	6.6	410	71.37009
18	4	22.13	BO	168	0.14	8.3	565	79.13102
19	2	198.02	SC	108	0.07	2.4	101	51.53278
19	2	198.03	SC	112	0.07	2.3	104	51.16469
19	2	198.04	SC	126	0.07	3.1	105	50.79660
19	2	198.09	SC	109	0.07	2.9	97	51.55889
19	2	198.10	SC	120	0.07	2.9	97	51.53278
19	2	198.11	SC	123	0.07	3.3	100	51.53278
38	2	188.01	SC	173	0.25	2.9	320	
38	2	188.21	SC	161	0.25	3.5	320	

TABLE C.4-20: SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-20: UNSTAGED COMBUSTION IN DISTILLATE OIL-FIRED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	FUEL NITROGEN (LB/MILLION BTU)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
1	1	62.01	103	0.020	9.0	60.0	25.30756
1	3	66.01	123	0.020	5.9	350.0	55.03762
1	3	66.02	123	0.020	7.0	350.0	55.03762
1	3	66.03	116	0.020	5.5	350.0	55.02652
1	3	66.04	119	0.020	4.8	350.0	56.22275
1	3	66.05	104	0.020	2.8	350.0	56.03539
1	2	102.01	87	0.020	5.2	60.0	44.07734
1	2	102.02	106	0.020	8.2	60.0	33.63119
1	2	102.03	100	0.020	7.5	60.0	33.63458
1	2	102.04	92	0.020	5.1	60.0	33.63797
1	2	102.05	103	0.020	9.5	60.0	33.63797
1	2	102.06	90	0.020	5.3	60.0	44.07734
1	2	103.01	84	0.020	4.7	60.0	43.53317
1	1	107.01	79	0.020	3.1	60.0	52.53035
1	1	107.02	85	0.020	2.7	60.0	54.78223
1	1	107.03	92	0.020	4.5	60.0	41.36617
1	1	107.04	97	0.020	5.9	60.0	41.36201
1	1	107.05	96	0.020	5.2	60.0	40.24412
1	1	108.01	80	0.020	3.9	60.0	39.13017
1	1	108.02	84	0.020	3.6	60.0	53.66423
1	1	108.03	86	0.020	3.8	60.0	53.66423
17	2	7.01	164	0.006	5.3	320.0	85.66011
17	2	7.02	181	0.006	6.9	320.0	85.66011
17	2	7.03	203	0.006	7.8	320.0	85.66011
17	2	7.04	167	0.006	3.8	320.0	86.63352
17	2	7.05	204	0.006	5.8	320.0	107.12940
17	2	7.06	183	0.006	5.6	320.0	87.64244
17	2	7.07	165	0.006	5.5	320.0	68.12491
17	2	7.08	166	0.006	6.8	320.0	47.68260
17	2	7.09	158	0.006	8.2	320.0	31.13334

TABLE C.4-20 (Continued): SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-20: UNSTAGED COMBUSTION IN DISTILLATE OIL-FIRED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	FUEL NITROGEN (LB/MILLION BTU)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
17	2	7.10	181	0.006	5.7	320.0	85.66879
17	2	7.11	184	0.006	5.5	320.0	82.73149
19	1	52.01	71	0.003	3.6	60.0	49.73412
19	1	52.02	64	0.003	2.6	60.0	49.74420
19	1	52.03	76	0.003	4.3	60.0	49.73412
19	1	52.04	70	0.003	5.3	60.0	49.72405
19	1	52.05	66	0.003	3.6	60.0	49.73412
19	1	53.01	91	0.003	3.0	60.0	49.01371
19	1	54.01	83	0.003	4.5	60.0	39.46831
19	1	54.02	82	0.003	3.7	60.0	40.74148
19	1	54.03	85	0.003	5.7	60.0	40.73323
19	1	54.04	82	0.003	6.6	60.0	40.72911
19	1	54.05	82	0.003	4.3	60.0	41.21245
36	6	160.01	103	0.007	4.4	92.0	62.36190
36	6	160.02	98	0.007	6.8	82.0	55.02521
36	6	160.03	104	0.007	3.3	85.0	82.52941
36	6	160.04	93	0.007	3.6	83.0	69.71989
36	6	160.05	88	0.007	5.6	92.0	47.72250
36	6	160.06	89	0.007	5.5	88.0	55.00840
36	6	160.07	102	0.007	9.5	88.0	33.05210
36	6	161.01	103	0.007	5.7	92.0	55.04202
36	6	161.05	99	0.007	3.7	84.0	69.69150
36	6	161.06	108	0.007	2.5	86.0	72.44248
36	6	161.09	138	0.007	4.7	86.0	73.35948
36	6	161.10	99	0.007	9.1	87.0	33.91148
36	6	161.11	100	0.007	9.4	86.0	32.99496
36	6	161.12	108	0.007	9.0	88.0	32.99496
36	6	162.01	131	0.007	5.6	88.0	69.69150
36	6	162.02	87	0.007	5.9	89.0	71.51092
36	6	163.03	91	0.007	6.2	92.0	47.72250

TABLE C.4-21: SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-21:
STAGED COMBUSTION IN DISTILLATE OIL-FIRED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	TEST TYPE	NOX EMISSIONS (PPM)	FUEL NITROGEN (LB/MILLION BTU)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
36	6	161.01	NA	103	0.007	5.7	92.0	54.90196
36	6	161.02	SC	96	0.007	5.5	93.0	54.90196
36	6	161.03	SC	98	0.007	5.4	93.0	54.90196
36	6	161.04	SC	103	0.007	5.5	92.0	54.64078
36	6	161.07	SC	97	0.007	2.5	88.0	68.69878

TABLE C.4-22: SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-23:

UNSTAGED COMBUSTION IN NATURAL GAS-FIRED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
1	1	12.04	70	2.8	85.0	50.59983
1	1	12.05	45	0.5	60.0	70.93749
1	1	12.06	67	1.5	60.0	60.14079
1	1	12.07	71	4.2	60.0	48.11749
1	1	12.08	77	5.0	60.0	38.47457
1	1	12.09	32	12.0	60.0	19.23729
1	1	12.10	85	5.2	60.0	42.10280
1	1	12.11	57	0.6	60.0	57.73516
1	1	12.12	72	2.9	60.0	59.41910
1	1	12.13	71	2.3	60.0	55.32953
1	1	12.14	69	2.6	60.0	52.92390
1	1	12.15	72	3.1	60.0	52.92390
1	1	12.16	74	3.7	60.0	54.12671
1	1	12.17	72	4.5	60.0	54.12671
1	1	12.18	65	1.9	60.0	54.12671
1	1	12.20	83	2.9	60.0	56.53235
1	1	12.21	77	6.7	60.0	43.28389
1	1	12.22	68	8.8	60.0	34.24171
1	1	12.23	102	8.7	60.0	18.03496
1	1	12.24	53	0.2	60.0	56.53235
1	1	12.25	83	0.5	60.0	56.53235
1	1	12.26	84	1.5	60.0	56.53235
1	1	12.27	89	2.6	60.0	55.32953
1	1	12.28	94	3.6	60.0	56.53235
1	1	12.29	85	0.5	60.0	55.10115
1	1	12.30	77	6.7	60.0	43.30137
1	2	5.01	70	3.4	60.0	50.93411
1	2	5.02	76	4.0	60.0	54.12125
1	2	5.03	74	2.7	60.0	54.12125
1	2	5.04	72	6.9	60.0	45.70239
1	3	67.01	89	3.8	350.0	36.05031
1	3	67.02	83	3.8	350.0	73.29202

TABLE C.4-22 (Continued): SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-23:

UNSTAGED COMBUSTION IN NATURAL GAS-FIRED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
1	3	67.04	96	5.7	350.0	58.38517
1	3	67.05	95	6.4	350.0	59.62139
1	3	67.06	90	4.5	350.0	60.11824
1	3	67.07	77	2.7	350.0	60.09308
1	2	101.01	77	1.8	60.0	57.53863
1	2	101.02	78	2.2	60.0	39.92476
1	2	101.03	80	4.9	60.0	39.92476
1	2	101.04	74	6.4	60.0	39.92476
1	2	101.05	82	4.0	60.0	39.92476
1	2	101.06	83	4.7	60.0	41.09902
1	1	104.01	75	0.9	60.0	54.98927
1	1	105.01	80	1.8	60.0	54.98927
1	1	105.02	82	2.9	60.0	54.98927
1	1	106.01	82	2.6	60.0	55.67664
1	1	106.02	84	3.5	60.0	42.91741
2	2	13.01	135	2.2	60.0	43.19693
2	2	13.02	136	5.1	60.0	44.33369
2	2	13.03	132	4.0	60.0	44.33369
2	2	13.04	121	3.0	60.0	43.75793
2	2	13.05	111	1.1	60.0	55.54503
2	2	13.06	126	2.4	60.0	58.83025
2	2	13.07	104	2.2	60.0	48.53864
2	2	13.08	131	6.2	60.0	34.98965
2	2	13.09	139	8.5	60.0	28.45537
2	2	13.10	136	11.0	60.0	24.61736
2	4	69.01	101	3.8	60.0	48.18404
2	4	69.02	86	3.0	60.0	48.17916
2	4	69.03	83	4.5	60.0	48.18404
6	3	25.01	184	14.5	310.0	41.33714
6	3	25.02	235	13.0	310.0	48.70232
6	3	25.03	277	11.8	310.0	61.98009
6	3	25.04	350	11.5	310.0	73.23261

TABLE C.4-22 (Continued): SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-23: UNSTAGED COMBUSTION IN NATURAL GAS-FIRED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
6	3	25.05	302	11.5	332.0	63.54998
6	3	25.06	104	13.5	310.0	30.24199
6	3	25.07	209	12.0	310.0	53.06671
6	3	25.08	243	11.4	315.0	57.74456
6	3	25.09	249	10.8	315.0	57.37409
6	3	25.10	214	12.3	310.0	55.42487
6	3	25.11	330	13.1	307.0	55.19823
6	3	25.12	318	12.0	303.0	57.58689
6	3	25.13	262	11.1	297.0	55.11729
6	3	25.14	289	14.3	303.0	52.79831
9	1	15.01	241	2.6	400.0	53.99901
9	1	15.02	229	1.9	400.0	57.79293
9	1	15.03	157	1.4	400.0	54.18087
9	1	15.04	252	3.3	400.0	57.78132
9	1	15.05	188	1.5	400.0	56.57755
9	1	15.06	245	2.0	420.0	72.91682
9	1	15.07	214	1.8	430.0	52.36433
9	1	15.08	138	1.8	400.0	41.46697
9	1	15.09	200	1.8	395.0	47.54922
9	1	15.10	152	1.8	390.0	48.15110
9	1	15.11	203	2.6	390.0	49.35488
9	2	24.01	403	3.8	330.0	92.84532
9	2	24.02	404	3.5	340.0	100.94925
9	2	24.03	374	3.8	330.0	99.94743
9	2	24.04	355	4.0	325.0	85.46178
9	2	24.05	380	3.6	320.0	90.17227
9	2	24.06	377	3.2	322.0	90.17227
9	2	24.07	339	2.6	322.0	90.84520
9	2	24.08	354	3.9	322.0	90.84520
9	2	24.09	339	4.3	322.0	90.84520
9	2	24.10	352	3.6	322.0	90.17227
9	2	30.01	181	3.2	401.0	95.78203

TABLE C.4-22 (Continued): SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-23: UNSTAGED COMBUSTION IN NATURAL GAS-FIRED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
9	2	30.02	154	4.5	401.0	96.56075
9	2	30.03	194	5.6	401.0	96.56075
9	2	30.04	166	3.2	401.0	96.56075
9	2	30.05	171	2.5	401.0	96.56075
9	2	30.06	197	2.9	401.0	71.64185
9	2	30.07	195	2.4	374.0	71.64185
9	2	30.08	200	4.3	374.0	71.64185
9	2	30.09	195	5.0	374.0	71.64185
9	2	30.10	198	2.9	374.0	72.03120
9	2	30.12	215	4.5	401.0	92.71010
9	2	30.13	182	2.7	374.0	55.02314
9	2	30.14	205	3.1	392.0	100.84369
9	2	30.15	199	2.3	392.0	100.84369
9	2	30.16	218	4.1	401.0	100.84369
9	2	30.17	185	5.4	401.0	99.28626
9	2	30.18	191	3.0	392.0	101.23304
9	2	30.19	212	2.8	392.0	98.89690
9	2	30.20	217	2.3	401.0	101.23304
9	2	30.21	222	4.1	396.0	102.12374
9	2	30.22	216	5.1	406.0	102.12374
9	2	30.23	182	2.9	383.0	81.34091
9	2	30.24	168	2.9	374.0	68.07083
9	2	30.25	179	2.7	383.0	77.84271
9	2	30.29	183	2.7	383.0	77.48222
10	4	14.01	104	5.2	60.0	73.94458
10	4	14.02	102	6.0	60.0	76.59925
10	4	14.03	108	3.9	60.0	76.59925
10	4	14.04	110	2.5	60.0	77.84985
10	4	14.05	108	4.9	60.0	77.06822
10	4	14.06	115	3.7	60.0	95.38714
10	4	14.07	95	6.7	60.0	64.11267
10	4	14.08	90	7.9	60.0	47.65986

TABLE C.4-22 (Continued): SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-23:: UNSTAGED COMBUSTION IN NATURAL GAS-FIRED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
10	4	14.09	87	9.7	60.0	32.44642
10	5	80.01	96	7.2	60.0	87.54286
10	5	80.02	120	6.2	60.0	87.51633
10	5	80.03	135	5.6	60.0	87.54286
10	5	80.04	151	2.3	60.0	91.58330
10	5	80.05	154	3.9	60.0	91.58330
10	5	80.06	137	1.0	60.0	92.25671
10	5	80.07	137	5.4	60.0	67.29304
10	5	80.08	124	5.4	60.0	55.21934
10	5	80.09	107	7.1	60.0	39.36839
10	5	80.10	103	7.4	60.0	89.56308
10	5	80.11	94	8.1	60.0	124.29162
10	5	80.12	96	8.2	60.0	125.25363
10	5	80.13	124	6.9	60.0	147.45481
10	5	80.14	107	8.0	60.0	114.47913
10	5	80.15	107	7.4	60.0	114.47913
10	5	80.16	116	6.4	60.0	115.82594
10	5	80.17	163	3.9	60.0	118.51957
10	5	80.18	164	3.1	60.0	121.22544
10	5	80.19	161	2.0	60.0	119.97849
10	5	80.20	74	8.7	60.0	100.30718
12	26	75.01	171	6.0	660.0	62.29022
12	26	75.02	176	5.8	660.0	44.09537
12	26	75.03	191	5.5	660.0	52.57525
12	26	75.04	174	5.6	660.0	68.01419
12	26	75.05	203	5.3	660.0	76.66026
12	26	75.06	209	6.4	645.0	60.60670
12	26	75.07	200	6.1	640.0	61.32821
12	26	75.08	139	4.4	640.0	62.44204
12	26	75.09	190	5.5	640.0	62.29022
12	26	75.10	255	7.4	648.0	61.28011
12	26	75.11	173	5.4	660.0	62.42577

TABLE C.6-22 (Continued): SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-23: UNSTAGED COMBUSTION IN NATURAL GAS-FIRED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
12	24	75.12	160	5.3	660.0	62.58302
12	24	75.13	164	6.2	640.0	62.27395
12	24	75.14	163	6.7	645.0	62.42577
12	20	77.02	229	3.8	638.0	63.04041
12	20	77.03	250	3.5	627.0	60.26016
12	20	77.04	265	4.1	644.0	68.13814
12	20	77.05	235	4.9	610.0	52.63497
12	20	77.06	223	4.9	625.0	57.88327
12	20	77.07	234	4.7	635.0	62.98515
12	20	77.08	270	4.5	650.0	68.23391
12	20	77.09	291	4.2	665.0	73.48268
12	20	77.10	342	3.9	680.0	79.66872
12	20	77.11	327	4.5	655.0	68.40751
12	20	77.12	320	4.0	650.0	68.40751
12	20	77.13	287	3.5	640.0	68.40751
12	20	77.14	336	5.3	645.0	68.40751
12	20	77.15	358	6.2	645.0	67.09198
12	20	77.16	347	4.5	645.0	68.23391
12	20	77.17	245	5.8	645.0	66.75147
19	2	190.01	56	3.2	95.0	60.38532
19	2	190.02	59	3.7	110.0	52.78364
19	2	190.03	59	3.2	100.0	52.84251
19	2	190.04	60	2.8	98.0	46.04381
19	2	190.05	69	3.2	92.0	54.72974
19	2	190.06	83	2.6	115.0	54.35229
19	2	190.07	61	2.5	97.0	52.85321
19	2	191.01	54	2.0	100.0	61.89495
19	2	191.02	55	2.9	106.0	52.83716
19	2	191.03	55	2.0	111.0	52.83180
19	2	191.04	58	2.6	111.0	52.83180
27	1	109.01	113	4.6	60.0	122.09994
27	1	109.02	142	5.0	60.0	123.59480

TABLE C.4-22 (Continued): SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-23: UNSTAGED COMBUSTION IN NATURAL GAS-FIRED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	NOX EMISSIONS (PPM)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
27	1	109.03	159	3.9	60.0	128.49945
27	1	109.04	146	1.3	60.0	128.53859
27	1	109.05	101	6.9	60.0	32.96530
27	1	109.06	99	6.5	60.0	49.42286
27	1	109.07	104	6.1	60.0	57.73612
28	1	122.01	211	5.7	335.0	30.98201
28	1	123.01	172	4.1	338.0	31.28040
28	1	123.02	166	3.7	336.0	30.23160
28	1	123.03	197	6.2	333.0	31.28040
29	5	113.01	155	5.4	375.0	81.08703
29	5	113.02	154	5.3	380.0	81.08703
29	5	114.01	166	4.7	390.0	82.11283
29	5	114.02	162	4.0	390.0	82.78041
29	5	114.03	155	4.4	376.0	80.11008
29	5	114.04	160	3.2	375.0	79.44249
29	5	114.05	149	6.0	383.0	80.77766
32	4	140.01	149	6.8	390.0	57.66559
32	4	140.02	160	7.1	390.0	56.03311
32	4	141.02	213	4.1	398.0	56.02348
32	4	141.03	213	8.2	385.0	56.15356
32	4	141.04	206	6.6	388.0	59.20747
32	1	143.01	231	4.3	390.0	53.30804
32	1	143.02	231	4.5	390.0	53.95814
32	1	143.03	230	4.4	390.0	53.95814
32	1	144.01	235	4.4	390.0	52.00785
32	1	145.01	227	3.7	390.0	53.83256
32	1	145.02	224	3.1	390.0	53.95814
32	1	145.03	210	2.2	390.0	53.95814
32	1	146.01	207	4.0	390.0	39.19793
32	1	148.01	216	4.2	390.0	53.30804
32	1	148.02	229	4.2	390.0	53.30804

TABLE C.4-23: SHORT-TERM NO_x EMISSION DATA FOR FIGURE 4.3-24: STAGED COMBUSTION IN NATURAL GAS-FIRED BOILERS[54]

LOCATION NUMBER	UNIT NUMBER	TEST NUMBER	TEST TYPE	NOX EMISSIONS (PPM)	EXCESS OXYGEN (VOL. %)	COMBUSTION TEMP. (°F)	HEAT RELEASE RATE (1000 BTU/HR·FT·FT)
9	1.1	15.04	MA	252	3.3	400.0	57.74070
9	1.1	15.12	SC	228	4.4	385.0	49.32018
9	1.1	15.13	SC	210	3.0	384.0	49.32018
9	1.1	15.14	SC	190	2.4	385.0	49.32018
9	2.1	30.29	MA	183	2.7	383.0	92.44311
9	2.1	30.26	SC	102	3.4	388.0	92.44311
9	2.1	30.27	SC	105	3.8	388.0	94.76580
33	1.0	146.01	MA	207	4.0	.	39.24920
33	1.0	147.07	SC	146	4.4	.	39.60426
33	1.0	147.08	SC	156	4.4	.	38.96548
30	2.0	181.02	MA	233	3.2	350.0	.
30	2.0	183.44	SC	161	3.4	350.0	.
30	2.0	183.47	SC	102	2.9	350.0	.
30	2.0	184.01	MA	235	1.8	350.0	.
30	2.0	184.05	SC	110	2.1	350.0	.
30	2.0	185.03	MA	211	4.1	350.0	.
30	2.0	185.05	SC	117	2.6	350.0	.
29	100.0	208.06	MA	104	4.4	60.0	26.01929
29	100.0	209.01	SC	114	3.6	60.0	26.30332
29	100.0	209.02	SC	116	4.6	60.0	26.16946
29	100.0	209.03	SC	126	5.7	60.0	26.08108
29	100.0	209.04	SC	147	6.4	60.0	25.95898
29	100.0	209.05	SC	137	5.6	60.0	25.54517
29	100.0	209.06	SC	135	5.3	60.0	25.81652
29	100.0	209.10	SC	126	4.4	60.0	26.08108
29	100.0	209.11	SC	120	2.7	60.0	24.00947
29	100.0	209.12	SC	122	4.6	60.0	25.28061

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APPENDIX D

EMISSION MEASUREMENT AND MONITORING METHODS

D.1 EMISSION MEASUREMENT METHODS

Since the characteristics of the emissions from industrial boilers are similar to those from source categories for which new source performance standards (NSPS) have been promulgated (e.g., Subparts D and Da 40 CFR Part 60, Fossil-Fuel Fired Steam Generators and Electric Utility Steam Generators), it was not necessary to develop new or modified reference test methods for the data collection phase of this study. The emissions measured are criteria pollutants--particulate matter, oxides of nitrogen, and sulfur dioxide--and applicable manual reference test methods have been promulgated in Appendix A, 40 CFR Part 60. In addition, during the development of the Electric Utility Steam Generator NSPS, EPA promulgated continuous measurement compliance provisions using instrumental techniques for SO_2 and NO_x. Finally, the Agency promulgated specifications and operating requirements for continuous monitoring of opacity, SO_2 and NO_x in Appendix B, 40 CFR Part 60 and proposed revisions to the monitoring performance specifications in the Federal Register on October 10, 1979. As a result of extensive comments, the Agency reproposed requirements for SO_2 and NO_x on January 26, 1981. The procedures used in the data collection study are described below by pollutant.

D.1.1 Particulates

Under the Fossil-Fuel Fired Steam Generator and Electric Utility Steam Standards, the best systems of particulate control were not considered effective for sulfuric acid mist and EPA promulgated modifications of Method 5 to minimize the measurement of acid mist as particulate matter. These modifications allowed probe and filter sampling temperatures up to

160° C (320° F). Since the best systems of particulate control for industrial boilers do not effectively collect sulfuric acid mist, similar provisions are recommended for this standard.

When operating Method 5 at elevated temperatures, EPA has found that special care must be taken to monitor and maintain both probe and filter temperatures so that significant sulfuric acid mist will not be measured. This includes monitoring probe temperatures, in addition to the sample gas stream temperature following the filter, with calibrated thermocouples. The EPA is currently evaluating alternative analytical techniques to subtract acid contributions of particulate measurements. These include: 1) extracting free acid with 100 percent isopropyl alcohol and, 2) heating the filter and probe sample catches in the laboratory prior to weighing. These procedures would minimize the need to carefully maintain probe and filter temperatures. If these procedures are shown to have sufficient precision and accuracy, they will be proposed as alternative methods. In the interim, Method 5 operated at elevated temperatures is the recommended method for performance tests.

D.1.2 Sulfur Dioxide

EPA performed tests at four industrial boiler sites equipped with flue gas desulfurization systems during this study. Continuous emission measurement procedures were used to determine the SO_2 removal efficiency and emission rates from each system. The test procedures used were based on the continuous emission measurement requirements for new electric utility steam generators under Subpart Da 40 CFR Part 60. These procedures require that SO_2 be measured before and after the SO_2 control system. A continuous diluent analyzer is also required. If oxygen is measured as the diluent, it is necessary to determine the moisture content of the sample stream as analyzed.

The SO_2 measurement systems used in EPA tests consisted of three major subsystems - sample collection, analysis, and recording. A gas sample was extracted from the source through a filter and heated Teflon sample line system. The sample was then routed to the measurement analyzers for SO_2 and oxygen, which were connected in parallel. The outputs of the measurement equipment were recorded on analog chart recorders.

The analyzers used for SO_2 measurement were of the ultraviolet spectrophotometric type. Three different types of oxygen analyzers were used - paramagnetic, polarographic, and zirconium oxide cell. Since oxygen was measured as the diluent, data for moisture content were necessary. At some of the locations, refrigeration-permeation dryer systems were used prior to sample analysis. In those cases the sample was assumed as dry. At the remaining sites, no dryers were used and dew point techniques were used to correct for water content. By this procedure, the lowest temperature in the sampling and analysis system was located and that temperature was recorded daily. In addition, manual tests were performed to determine the actual source moisture content. The lower of the two determinations was used for emission calculations.

The emission measurement systems for each location were tested using the performance specification test procedures of Performance Specification 2, Proposed Revisions of October 10, 1979. After the systems were demonstrated to conform to the performance specifications, the data collection portion of testing was started. During this nominal 30 day period, the instruments were calibrated daily. Additional reference Method 6 samples were collected for quality assurance purposes at weekly intervals, when possible. At the end of the test period, the performance specification tests were repeated.

The minimum data requirements were as follows:

- Each sample point must be analyzed at least once in each fifteen minute clock interval.
- In order to calculate a 1 hour average for a SO_2 result, at least two of the four 15 minute data points for each parameter (SO_2, O_2) must be available.
- In order to calculate a 24 hour (one calendar day) average result, at least 18 one hour averages must be available.

These requirements are similar to those for Subpart Da procedures, except that for data collection purposes, the longest averaging period considered was 24 hours versus the 30 day averaging period of Subpart Da.

D.1.3 Nitrogen Oxides

EPA performed studies at six industrial boiler sites where various combustion modifications were made for NO_x reduction. Continuous emission measurement procedures were used to determine the NO_x emissions before and after the modifications. The procedures used were based on the continuous emission measurement requirements of the electric utility NSPS. Oxides of nitrogen were measured using chemiluminescence analyzers.

This assumption was validated by the results of the relative accuracy portions of the performance specification tests. Both oxygen and carbon dioxide were measured as diluents. The sample stream was passed through a condenser-dryer system prior to being introduced to the instrument system. Performance specification tests and daily calibrations were performed as described in the sulfur dioxide discussion above. The minimum data requirements for computing averages were also similar.

D.2 COMPLIANCE TEST METHODS

The reference test methods and procedures available for determination of compliance with an emission limitation, along with the costs of each type procedure, are discussed in this section. The choice between the alternatives depends primarily on the averaging time necessary to confidently establish an average emission level. The manual reference methods (Method 5 for particulates, 6 for sulfur dioxide, and 7 for nitrogen oxides) are generally only applicable for short term tests that yield essentially one hour to three hour averages. If it is determined that a longer term average is required, automated measurement techniques are more appropriate. However, if the automated measurement methods incorporate sampling and analysis principles that are different from the manual measurement techniques, it is necessary that results from these methods be proven comparable to results of the manual techniques. For example, for instrumental sulfur dioxide measurement, comparative tests must be performed initially and at specified intervals using Method 6 to demonstrate that the results from the two techniques were within an allowable difference.

D.2.1 Emission Measurement Options

The measurement procedure options are discussed in this section. For clarity, the procedures are grouped as alternatives by pollutant measured.

D.2.1.1 Particulate

As with the Electric Utility Steam Generator Standard, the best systems of particulate control for industrial boilers are not effective for sulfuric acid removal. Therefore, Method 5 modified to allow probe and filter temperatures up to 160° C (320° F) is recommended as the compliance method. In addition, the use of Method 17 is recommended as an alternative to Method 5 whenever the average stack gas temperature at the sampling location does not exceed 160° C (320° F).

D.2.1.2 Opacity

Method 9, "Visual Determination of the Opacity of Emissions from Stationary Sources," is recommended as the compliance test method for opacity. This method is applicable for the determination of opacity of effluent streams emitted from stacks.

Continuous monitors for opacity are not recommended for use in determining compliance with this regulation because an absolute accuracy check is not possible with the current state-of-the-art opacity monitoring systems.

D.2.1.3 Sulfur Dioxide

Reference Method 6

EPA Method 6 is the manual method for short term determination of SO_2 emissions from stationary sources. Method 6 is a wet chemical sample collection and analysis procedure that requires a working knowledge of emission sampling techniques and laboratory analysis methods. Method 3 (O_2 and CO_2) must be run concurrently in order to obtain SO_2 emission data in terms of the standard. The manpower requirements are one to two people for about one day to complete three to nine test runs and analyses.

Use of Method 6 for emission monitoring purposes would be limited to periodic tests (i.e., weekly, monthly, etc.) because of the high cost and manpower requirements. Enforcement would be simplified as the regulatory agency need only check the test report to establish compliance.

A second advantage is that, although the cost of each test is high, the annual cost of periodic tests could be less than for continuous monitoring or on-site coal analysis, if the repetition period is appropriately selected.

A disadvantage of the periodic emission test approach is that continuous compliance data cannot be collected.

The Agency has proposed Method 6A, which combines the SO_2 measurement capabilities of Method 6 with a CO_2 measurement, using ascarite absorbent, so that measurement of SO_2 emissions in terms of the standard can be completed with one sampling train. This would eliminate the need for Method 3 measurements and decrease the manpower needs for conducting manual tests. Method 6A was proposed in the Federal Register on January 26, 1981.

Automatic SO_2 Sampling

EPA has developed Method 6B (also proposed in the Federal Register on January 26, 1981) that makes use of the combined SO_2 and CO_2 measurement capabilities of Method 6A in a long-term sampling method. Method 6B can be operated intermittently for 24 hours using a timing switch to obtain representative daily samples. Alternatively, a low-flow (50 ml/min) pump may be used to sample continuously over 24 hours or intermittently over longer periods (3 to 7 days) to obtain a longer-term average value. Method 6B can be applied as an emission monitoring method by operating the equipment automatically at the appropriate emission points and analyzing the collected samples on-site.

Manpower requirements are less than for Method 6 as only one test train is operated at a sampling point instead of three runs that constitute a Method 6 test. One person can prepare fresh chemicals, remove the used collection section, replace with a fresh train, and analyze the collected samples in less than one-half day. The training necessary is a knowledge of simple laboratory techniques.

The advantage of using Method 6B as an emission monitor over the periodic use of Method 6 or Method 6A is that Method 6B can establish compliance on a continuous or semi-continuous basis. The capital costs and annual costs for operating Method 6B are less than for a continuous monitoring system.

One disadvantage associated with Method 6B is that real time data are not provided. All data are produced one day to one week following the emission occurrences.

The manual methods above are applicable for determining control efficiency across sulfur control equipment. Methods 6, 6A, and 6B have been used for this purpose and have proved satisfactory.

Continuous Emission Measurement

EPA has promulgated procedures by which sulfur dioxide and oxides of nitrogen can be measured on a continuous basis using the instrumental techniques. The advantage of these procedures is that the averaging time for an emission limitation can be much longer than for manual techniques. By using a longer averaging period, short term peaks and normal variations in emissions can be smoothed. Also, a continuous record of emissions is provided. A disadvantage of this procedure is that relatively sensitive and sophisticated equipment is required, and in some cases daily inspection and maintenance labor are necessary.

The continuous measurement procedures promulgated by EPA for Electric

Utility Steam Generators would be applicable on a technical basis, not considering cost. That regulation requires analyzers to be installed and operated to measure sulfur dioxide before and, if applicable, after a control device. In order to express the pollutant emissions in terms of the standard (nanograms/joule), a diluent analyzer is required. These instruments may measure either oxygen or carbon dioxide. In addition, if oxygen measurement is performed, a method must be available to establish the moisture content of the sample gas.

Specifications for selection and installation of the analyzer systems are given in 40 CFR 60 Appendix B, Performance Specification 2. Also included in this reference is a series of test procedures to which the instrument system is subjected in order to establish stability and accuracy. These tests are intended to determine the drift stability and calibration repeatability using calibration materials, and to establish accuracy by performing comparative tests using Reference Method 6 for SO_2.

Once an analyzer system has been tested to show conformance with the performance specifications, it is placed in service for data collection. The minimum data requirements are that at least one data point be obtained for each fifteen (15) minute clock period, and that at least two of these data points must be available to calculate an average for a 1 hour interval. The Electric Utility NSPS is on a 30 day average basis. At least 18 of 24 hour averages each calendar day and 22 of 30 days must be available to calculate a 30 day average.

In order to insure the continuing quality of the data obtained by the continuous emission measurement system, EPA is currently developing requirements for quality assurance testing. Daily calibration results would be used as a measure of precision, and relative accuracy tests using the reference methods would be performed at quarterly or semi-annual intervals to determine accuracy.

Continuous measurement systems can be used to determine emission rates for SO_2 and also to determine removal efficiency for SO_2 control devices. Instrument systems can also be used in conjunction with fuel monitoring and analysis for SO_2 to determine removal efficiency. The testing and calculation procedures required for these alternatives are included as Reference Method 19 in Appendix A, 40 CFR 60. The quantity of data generated by a continuous measurement system would probably require that the calculations be performed automatically by a data retrieval and reduction system.

Fuel Analysis

The agency has reviewed and considered use of fuel sampling and analysis to determine potential sulfur emissions from fossil fuel-fired boilers. This section discusses two major areas of fuel measurements: coal sampling and analysis, and oil or gas sampling and analysis.

Coal Sampling and Analytical Options

The Agency relies on ASTM (American Society for Testing and Materials) reference methods which clearly specify procedures for collecting and analyzing representative coal samples. Mechanical, regularly spaced, increment collections provide the most representative results. The sample analyses required are total sulfur content and the fuel high heating value from which potential sulfur emissions in terms of the standard (ng/J) can be calculated.

The ASTM procedures that apply are D2234 for coal sampling, D2013 for sample preparation, D271 for sulfur content analysis, and either D271 or D2015 for heating value analysis. Several alternative analytical procedures are available in the form of instrumental measurements of fuel sulfur and heat contents. ASTM has not approved these procedures as the procedures have not demonstrated a precision equivalent to the approved ASTM methods. Others have claimed adequate or superior precision capabilities for these procedures. The Agency will rely on the ASTM methods until sufficient data are provided to demonstrate the adequacy of alternative procedures.

The location specified for the collection of the coal sample can affect the accuracy and the cost associated with each reported value. The first option is to require the user to obtain from the coal vendor (the mine operator or fuel treatment plant operator) a certified analysis of the delivered coal. This certification will identify the coal delivery, the analysis results for that coal, and document that the sampling and analytical procedures specified by the Agency were followed. The advantages of this option are: 1) the cost of sampling can be spread by the vendor to all purchasers resulting in a lower cost per sample, and 2) compliance determination is simplified as the enforcement agency need only check the fuel certification.

One disadvantage of this approach is the difficulty in applying an enforcement action if the certified fuel analysis is incorrect. The coal vendor is not the affected facility for this regulation, so direct enforcement and policing of the fuel sampling and analytical procedures is not possible.

A second disadvantage of the vendor supplied certification option is the difficulty in correlating the fuel analyses data with the emission averaging time. A short averaging time for the emission standard (one day or less) would require strict accounting and traceability for each parcel of delivered coal. This may not be possible or practical at most industrial boiler facilities. A longer averaging time (10 to 30 days) would allow an easier accounting of potential emissions with the use of coal analyses and coal supply information.

The second sampling location option is a point in the feed to the boiler. This point could be in the raw-coal feed stream or in the fired-coal feed stream. Analysis of a sample from the raw-coal feed stream would provide somewhat higher potential sulfur emissions than would analysis of an as-fired pulverized coal sample. The difference would be the amount of pyritic sulfur and other sulfur compounds removed in the pulverizing process. Analyses of the raw coal samples would also show more variability than would analyses of the pulverized coal samples. This could result in the requirement for a greater sampling frequency for raw coal than for pulverized coal.

The primary advantage of on-site coal sampling is the direct accountability of the sulfur emissions. This helps in establishing shorter averaging times for the standard as there is better correlation between the analytical data and the emissions produced. Longer averaging times may be established, as well, using daily (or other short term period) analytical values in determining a long term average. The enforceability of on-site coal sampling is more direct than for other approaches as the boiler operator is directly responsible for the analytical data.

A major disadvantage with the on-site, coal sampling approach is the high cost of sampling and sample preparation. Automatic coal samples, the most convenient and accurate method, are quite costly and require frequent and regular maintenance. Coal sampling equipment that meet ASTM sampling requirements cost from $20,000 to over $200,000 depending on the degree of automatic control included. Less automatic devices are more man-power intensive in the operation of the samples and in preparation of the sample. Collection and preparation of daily samples can cost from $15,000 to over $50,000 on an annual basis and analysis costs are approximately $50 to $100 per sample.

Oil and Gas Sampling and Analytical Options

Oil and gas sampling and analytical procedures are not as expensive or involved as for solid fuels. This is because the variability of sulfur content in oils and gas is very low compared to the variability in coal. The inherently lower concentrations of sulfur and the low variability allows for the use of less frequent, manual sampling procedures for oil and gaseous fuels. Grab samples from oil feed lines or from storage tanks are sufficient for obtaining representative liquid samples. Procedures for collecting representative samples of gaseous fuels are ASTM D1145 and D1247 for natural gas and manufactured gas, respectively. Analysis of fuel oil sulfur content can be done with several different ASTM procedures: D240, D1551, D1552, or D3177. D240 should be used for determination of fuel oil high heating value. The ASTM methods for analysis of fuel gases are D1072 for total sulfur and D1826 for calorific value. Other ASTM procedures for these measurements are also available.

The frequency of sampling required for liquid and gaseous fuels is dependent on the averaging time for the emission standard. Daily samples from fuel feed lines can provide adequate data for one day or longer averaging periods. Other sampling schemes or averaging determinations would be necessary for shorter periods. The location of the sample collection and analyses is limited to the feed lines for gaseous samples. Liquid fuels could be analyzed by the supplier if bulk deliveries are made to the user. However, the ease of sample collection and the low frequency of collection make the requirement for on-site sampling feasible and more desirable from the Agency's point of view.

A disadvantage of any fuel sampling and analysis method is that the data produced are not sufficient for determining efficiency of flue gas desulfurization (FGD) units. A measure of FGD emissions is required in addition to fuel sulfur content data. Another disadvantage is that fuel analyses data provide no information regarding NO_x emissions. Again, a separate emission measurement is required.

D.2.1.4 Nitrogen Oxides

Reference Method 7

EPA Method 7 is the manual method for measurement of NO_x emissions from stationary sources. Method 7 is a grab sampling, wet-chemical collection procedure with a colorimetric analysis procedure. The analytical method requires considerable laboratory time and skills to complete successfully. As with Method 6 measurements, Method 3 must be conducted simultaneously with the Method 7 tests in order for the NO_x concentration data to be converted to units of the standard. The manpower requirements and costs for analyses are approximately the same as for Method 6.

Use of Method 7 for emission monitoring purposes would be limited to the same type of use as discussed for Method 6. In turn, the advantages and disadvantages are also similar.

The Agency has explored the use of alternative analytical methods for Method 7. In particular, the Agency has studied the ion chromatographic and the specific ion electrode procedure. Both of these procedures have proven successful for combustion emission samples and the Agency is preparing written procedures describing the use of these analytical methods.

Continuous Emission Measurement

The requirements for continuous measurement of NO_x emissions are essentially identical to those described for SO_2 continuous measurement systems. Commercial instruments are available to measure oxides of nitorgen as NO, or with an appropriate oxidation device, as NO_2. Either type has been shown to achieve the performance specifications of Performance Specification 2, Appendix B, 40 CFR Part 60. The only significant difference between the requirements for NO_x measurement is that only the emission rate is determined.

D.2.2 Compliance Method Costs

The costs for performing the various types of compliance tests are discussed in this section. These costs are current to September 1980, when this evaluation was performed. The assumptions leading to the estimated cost are also presented. For clarity, the procedures are grouped according to the type of measurement.

Manual Reference Procedures

The applicable procedures are Method 5 for particulates, Method 6 for SO_2, and Method 7 for NO_x. Each procedure is labor intensive and results in a short-term average result, usually consisting of triplicate one hour runs. EPA Method 3 for diluent determination is necessary for Methods 5, 6, and 7, and can be performed concurrently.

The cost estimate for performing the emission measurement includes all the procedures necessary to report results in terms of the required emission factor or removal efficiency.

The costs for performing these tests are presented in Table 1. These costs are based on an average contracted effort with a labor charge of $30/hour. Also included are average travel charges. If a facility has in-house measurement capabilities, or more than one pollutant is measured during a test, the costs will be reduced.

Automated Reference Procedures

The only automated reference method emission measurement that has been demonstrated is for SO_2. The primary variable that affects the cost of this procedure is the length of time that the sampler operated before the absorbing solution is recovered and analyzed. The estimated costs for this procedure are presented in Table 2. Both capital and operating costs are necessary since an initial investment for dedicated equipment is required. The operating costs are based on average maintenance sample recovery, and analytical labor requirements at $30/hour.

TABLE 1. MANUAL REFERENCE PROCEDURE TEST COSTS
(SEPTEMBER 1980 $)

Pollutant Measured	Method	Cost, $/test
Particulates, outlet only	5	10,000
SO_2, outlet only	6	3,000
SO_2, removal efficiency	6	5,000
NO_x, outlet only	7	5,000

TABLE 2. AUTOMATED SO_2 REFERENCE PROCEDURE COSTS (SEPTEMBER 1980 $)

Option	Cost Capital $	Operating $/yr
Emission rate measurement		
1-day interval	$2000	$29,000
3-day interval	2000	14,000
7-day interval	2000	7,000
Removal Efficiency		
1-day interval	4000	58,000
3-day interval	4000	28,000
7-day interval	4000	14,000

Estimates are presented for 1 day, 3 day, and 7 day sampling intervals; and for emission rate and SO_2 removal efficiency determinations. Finally, the facility is assumed to have only one inlet duct and one outlet emission duct. For systems with multiple inlets or outlets that require measurements, the costs will be increased.

Continuous Emission Measurement

Continuous emission measurement procedures are applicable for SO_2 and NO_x. These emissions can be measured and reported continuously in terms of emission factors of nanograms/joule. The analyzer systems can be tested and demonstrated to yield results equivalent (within a specified accuracy) to the manual reference procedures.

The continuous emission measurement procedures require that the pollutant and a diluent concentration be measured continually. In some cases, it is also necessary to perform additional tests, such as monitoring dew point temperature to determine moisture content of the sample. Since analyzers are not primary standards for SO_2 or NO_x, it is necessary that comparability or relative accuracy tests be performed initially. To assure data quality, regular systems calibrations and relative accuracy checks are necessary.

The costs for continuous emission measurement systems for SO_2 and NO_x are presented in Table 3. The total costs are divided into capital, installation, and operating charges. The estimates are based on a boiler equipped with an FGD system with one inlet duct and one outlet duct; with a physical layout that allows all system components to be installed within about a 100 foot radius; that no system components are

TABLE 3. SO_x/NO_x CONTINUOUS EMISSION MEASUREMENT PROCEDURE COSTS (SEPTEMBER 1980)

	Initial Costs				Operating Costs			
Option	Capital	Installation	Initial Performance Test	Total Initial Capital,$	Routine Labor	Operation Materials	Quality Assurance Test	Total Operating $/Year
Outlet Emission	20,000	10,000	10,000	40,000	10,000	1,000	20,000	31,000
FGD Efficiency	30,000	14,000	14,000	58,000	20,000	2,000	40,000	62,000
NO_x Outlet Emission	20,000	10,000	10,000	40,000	10,000	1,000	20,000	31,000

shared, and that an automatic data reduction system dedicated to emission reporting is necessary. The actual costs will vary from site to site depending on the measurement system chosen, the degree of automation, and the amount of labor necessary to keep the systems operational. The costs in Table 3 are median estimates and cannot be used as universally precise values.

Fuel Sampling Procedures

Fuel sampling for a compliance technique is only applicable to SO_2 determinations. Also, fuel sampling can only measure uncontrolled emissions and cannot indicate emissions after a control device. However, fuel analysis can be used to determine inlet SO_2 rates for use with outlet measurements for SO_2 removal efficiency data.

Fuel sampling can be by automatic or manual techniques. For a result with the least amount of uncertainty, a continuous automatic sampler is required. If an automatic sampler is not used, the primary variable that determines annual cost is the frequency of sampling. The costs for various sampling and analytical options are presented in Table 4.

TABLE 4. FUEL SAMPLING PROCEDURE COSTS
(SEPTEMBER 1980 $)

	Sampling			
Option	Capital	Labor	Analysis	$/Sample
Coal Fired				
Automatic Sampler	$20,000-$200,000	Nil		$50-100
Manual samples, $/sample	Nil	$300-$1000		$50-100
Oil/Gas Fuel				
Manual Sampling $/Sample	Nil	$100-$1000		$50-100

D.3 CONTINUOUS MONITORING

The purpose of continuous monitoring is to provide qualitative or semi-quantitative measures of continued proper operation and maintenance when short term manual tests are used to determine compliance with an applicable regulation. The most significant difference between continuous emission measurement and continuous monitoring is that for monitoring purposes, the data do not have to be accurately and precisely correlated to true emission levels. In many cases, simpler and less expensive instrumentation systems can be used. For example, when EPA Method 5 is used as the measure of compliance with a particulate emission limitation, the average test duration would be about three hours. Since it is impractical to perform manual tests continually, a transmissometer can be specified as a procedure to obtain continuous operation information. Since the mass emission rate and opacity of the emission are generally related, an increase in opacity usually indicates an increase in particulate emissions. However, since a general, precise correlation between mass emission rate and opacity does not exist, the results of continuous opacity measurement cannot generally be used to enforce a mass emission limitation. In those cases where a transmissometer cannot be used for monitoring (e.g., a location where condensed water vapor is present), A surrogate operating parameter can be monitored. An example would be monitoring of the pressure drop across a wet venturi scrubber. The available procedures for continuous monitoring are presented below.

D.3.1 Particulates/Opacity

The most direct monitoring procedure for particulate emissions is by measuring opacity. The utility of transmissometers for monitoring the opacity of emissions from combustion sources has been demonstrated. Transmissometer systems meeting the design and performance criteria of Performance Specification 1: "Performance Specifications and Specification Test Procedures for Transmissometer Systems for Continuous Measurement of the Opacity of Stack Emissions," (40 CFR 60, Appendix B) are commercially available. These systems are applicable for use on industrial boilers.

A recent (fall 1980) survey of several instrumentation vendors indicates that the capital cost for an opacity monitoring system is between \$10,000 and \$15,000. This cost is for a single unit with an analog data recorder. Digital data handling systems which can handle up to four opacity monitoring systems are available for an additional \$10,000 and programable digital systems for handling multiple monitors on a single source (i.e., SO_2, NO_x, opacity) are available for \$25,000 - \$30,000 including software.

Installation and start-up costs for a new source where ports and access platforms are installed during construction are estimated at under \$5,000. The cost of conducting the performance test required in Specification 1 is estimated at between \$3,000 and \$5,000 per instrument while maintenance costs are estimated at \$3,000 to \$10,000 per year.

For the cases where instrumental measurement of opacity is not technically possible or economically feasible, it may be acceptable to measure a process operation parameter. Particulate scrubbers are an example of a case where opacity measurement is usually not technically possible due to uncombined water interferences. Gas phase pressure differential and scrubber liquid flow have been specified in previous regulations as indicators of proper maintenance and operation of these units. However, for electrostatic precipitators, fabric filters, or high efficiency mechanical separators, there may not be a single operating parameter that is a reliable indicator of proper operation.

D.3.2 Sulfur Dioxide

The choice of a monitoring approach for sulfur dioxide depends on the type of regulation and the control strategy used to achieve that requirement. If a regulation is in terms of an emission limit, an SO_2 analyzer can be used to measure the concentration in the flue gases. Analyzer systems capable of meeting the performance criteria of Performance Specification 2, Appendix B 40 CFR 60 are commercially available. If an emission regulation is achieved by using low sulfur fuels, routine sampling and analysis can also be used as an operations monitoring technique. For the case where a removal efficiency is specified, measurements are necessary before and after a control device. An analyzer is necessary after control; inlet data may be obtained either by an analyzer or by fuel monitoring. There may be some cases where an operating parameter could be used as an indicator of operations. At some of the industrial boiler facilities equipped with flue gas desulfurization systems tested by EPA, the pH of the scrubbing liquid was a good qualitative indicator of operation at design removal efficiencies. However, the usefulness of monitoring this parameter could vary from system to system and the correlation of pH to removal efficiency would be site specific.

The cost of an instrument system for monitoring SO_2 and a diluent at a single location is estimated to range from \$20,000 to \$30,000. Installation costs are estimated to be \$10,000. Annual operating and maintenance costs, at one-half hour per day at \$30/hour are \$5,500.

This system would include an analog chart recorder. Systems for automatic data handling are commercially available with costs ranging from \$10,000 to \$30,000. For multiple locations, the costs can be assumed additive; however, many parts of the overall system could be shared in some designs, resulting in reduced overall cost. Each system would require an initial performance specification test, estimated at \$10,000 per measurement location.

Fuel analysis costs have been discussed in Section D.2.2.

D.3.3 Oxides of Nitrogen

The continuous monitoring of nitrogen oxides can be accomplished using instrumental analyzers. Commercial systems that can meet the requirements of Performance Specification 2, Appendix B 40 CFR 60 are available. Instrumental measurements are usually the only way to obtain monitoring information for NO_x since there is not a simple relationship between emission rates and operating parameters (e.g., excess air or combustion temperature).

Instrument systems for NO_x monitoring are similar to those required for SO_2 monitoring, and the capital and operating costs are essentially the same.

APPENDIX E

EMERGING TECHNOLOGY MODEL BOILER IMPACT ANALYSIS

Chapters 6-8 presented a model boiler analysis of a variety of emission control techniques applied to different sizes and types of industrial boilers. This appendix is included as a supplement to these chapters. It provides a separate model boiler impact analysis for selected "emerging control technologies". The technologies selected for evaluation are:

- Selective Catalytic Reduction (SCR)
- Low-Btu Gasification (LBG)
- Coal/Limestone Pellets (CLP)
- Fluidized Bed Combustion (FBC)

These technologies, while generally not applied to commercial scale industrial boilers, offer potential for significant near-term penetration into the industrial boiler market. Chapter 4 provides process descriptions and a discussion of the status of development of each of these technologies.

Several Individual Technology Assessment Reports (ITAR's) have been prepared and form the basis for the majority of the data presented in this Appendix.[1,2,3] Since the emerging technologies are still, by definition, under development, the data is inherently less accurate than that presented in Chapters 6-8. For this reason, comparisons between Chapters 6-8 and this appendix should be made with caution.

Except for LBG, application of each emerging technology results in the reduction of either SO_2, PM, or NO_x (LBG reduces all three major emission species relative to conventional combustion of coal). Except as noted, the impacts presented in this appendix are associated with the emerging technology only and do not include impacts associated with the use of other control techniques used to control other emission species.

The organization of this appendix is analagous to the organization of Chapters 6-8. Section E.1 defines the model boilers in terms of boiler specifications, control device specifications, and achievable emission levels. Section E.2 presents a brief analysis of the environmental and energy impacts. Finally, Section E.3 reviews the costs associated with the emerging technologies.

E.1 EMERGING TECHNOLOGY MODEL BOILERS

Table E-1 presents the five emerging technology model boilers examined in this appendix. Both uncontrolled and controlled emissions are indicated. As noted in Table E-1, the LBG, CLP, and FBC technologies use control methods involving the boiler and/or fuel preparation system rather than a flue gas treatment device. In these cases, an uncontrolled high sulfur coal-fired spreader stoker is assumed representative of uncontrolled emissions.

Two oil-fired units are included to assess use of selective catalytic reduction (SCR) NO_x controls. The parallel flow system is applied to a residual oil-fired unit where particulate matter might plug a fixed bed system. The distillate oil-fired unit emits very little particulate matter and is thus suitable for the fixed bed system. The remaining three model boilers input coal as the raw fuel. In low-Btu gasification (LBG) the coal is gasified at the boiler site prior to combustion in a gas-fired boiler, resulting in reductions in all three major emission species. The coal/limestone pellet (CLP) SO_2 control technique involves firing a pelletized coal and limestone mixture in a conventional spreader stoker. Fluidized bed combustion (FBC) also uses limestone as an SO_2 sorbent. However, the coal and limestone are introduced separately with firing occurring in a bed fluidized by forced air.

Table E-2 presents the model boiler and control device specifications used in this analysis. As noted, the SCR systems are applied to boilers identical to the standard oil-fired boilers defined in Chapter 6. The LBG technology uses a modified natural gas-fired boiler to fire the low-Btu gas produced in the gasifier. The modifications are relatively minor, but include a derating of the boiler due to the lower flame intensities associated with combustion of low-Btu gas. The CLP technology

TABLE E-1. EMERGING TECHNOLOGY MODEL BOILERS

Model[a] Boiler	Boiler Capacity MW (10^6Btu/hr)	Emission(s) Controlled	Emission Levels ng/J (lb/10^6Btu) Uncontrolled[b]	Emission Levels ng/J (lb/10^6Btu) Controlled	Emission Reduction (percent)
RES-150-SCR/PF	44 (150)	NO_x	171 (0.400)	17.1 (0.040)	90.0
DIS-150-SCR/FB	44 (150)	NO_x	103 (0.240)	10.3 (0.024)	90.0
HSC-150-LBG	44 (150)[d]	NO_x	273 (0.630)	86.0 (0.200)	68.3
		SO_2	2450 (5.70)	150 (0.500)	91.2
		PM	2500 (5.82)	13.0 (0.030)	99.5
HSC-150-CLP	44 (150)	SO_2	2450 (5.70)	1104 (2.56)	55.0
HSC-150-FBC	44 (150)	SO_2[c]	2450 (5.70)	245 (0.570)	90.0

[a] RES = residual oil-fired; DIS = distillate oil-fired; LBG = low-Btu gas-fired; HSC = high sulfur coal fired; SCR/PF = selective catalytic reduction, parallel flow; SCR/FB = selective catalytic reduction, fixed bed; CLP = coal-limestone pellets; FBC = fluidized bed combustion.

[b] For oil-fired boilers, uncontrolled emissions are actual emissions prior to SCR control. For other boilers, a spreader stoker is assumed representative of uncontrolled emissions.

[c] FBC boilers typically achieve a slight (less than 20%) NO_x reduction compared to a conventional spreader stoker, however, available data is inconclusive (see Chapter 4).

[d] Heat input to low-Btu gas-fired boiler (not heat input to gasifier).

TABLE E-2. SPECIFICATIONS FOR EMERGING TECHNOLOGY CONTROL TECHNIQUES

Selective Catalytic Reduction/Parallel Flow (SCR/PF)

Reactor Configuration	Parallel Flow
Catalyst	V_2O_5 or Fe-Cr on alumina substrate
Catalyst Shape	Honeycomb or parallel plate
NH_3:NO_x Ratio	1:1 (molar)
Reactor Temp.	350-400°C (688-788°F)
Gas Velocity	2-10 m/sec (6.6-33 ft/sec)
Bed Depth	1-6 m (3.3-30 feet)
Pressure Drop	0.03-0.16 kPa (0.12-0.63 in H_2O)

Boiler Specifications as per Table 6-5 (RES-150)

Selective Catalytic Reduction/Fixed Bed (SCR/FB)

Reactor Configuration	Fixed Packed Bed
Catalyst	V_2O_5 or Fe-Cr on alumina substrate
Catalyst Shape	Pellets, 0.33 cm (0.13 in) diameter
NH_3:NO_x Ratio	1:1 (molar)
Reactor Temp	350-400°C (688-788°F)
Gas Velocity	1-1.5 m/s (3.3-4.9 ft/sec)
Bed Depth	0.2-0.6 m (0.66-2.0 ft)
Pressure Drop	0.040-0.080 kPa (0.16-0.32 in. H_2O)

Boiler Specifications as per Table 6-4 (DIS-150)

Low-Btu Gasification (LBG)

Gasifier Type	Wellman-Galusha
Acid Gas Removal	Stretford
Coal Feed	High Sulfur Coal (see Table 6-8)
System Components	Coal preparation, gasifier, quench towers, ESP, Stretford H_2S removal unit, Claus sulfur recovery unit

TABLE E-2. (CONTINUED)

Low-Btu Gasification (LBG) (continued)	
Gas Composition	N_2 - 46% CO - 26% H_2 - 13% CO_2 - 3% CH_4 - 2.6% H_2S - 0.7% (before Stretford)
Gas Heating Value	5.62 MJ/m^3 (151 Btu/ft^3)
Capacity Factor	0.6
Boiler is similar to NG-150 presented in Table 6-3 with modifications to burn low-Btu gas.	
Coal-Limestone Pellets (CLP)	
Boiler Type	Spreader Stoker
Thermal Input	44 MW (150 x 10^6 Btu/hr)
Boiler Efficiency	81% (estimated)
Fuel	Coal/Limestone Pellets
Coal Type	High Sulfur Coal (see Table 6-8)
Sorbent Type	Limestone ($CaCO_3$)
Ca:S Ratio	3.5:1 (molar)
Capacity Factor	0.6
Fluidized Bed Combustion (FBC)	
Boiler Type	Atmospheric FBC with once-through sorbent processing
Thermal Input	44 MW (150 x 10^6 Btu/hr)
Boiler Efficiency	82.8%
Bed Temperature	843°C (1550°F)
Capacity Factor	0.6
Fuel	High Sulfur Coal (see Table 6-8)
Sorbent	Limestone ($CaCO_3$ with average particle size of 0.5 mm)
Ca:S Ratio	3.3:1 (molar)
Capacity Factor	0.6

uses a modified spreader stoker. Very little data is presently available to assess the full extent of the modifications necessary to adapt a spreader stoker to CLP firing. Some derating of the unit is anticipated as well as modifications to the fuel feed and bottom ash removal mechanisms. The FBC technology involves a radically different boiler design compared to conventional boilers.

A uniform 44 MW (150 x 10^6Btu/hr) capacity is specified for all the emerging technology model boilers. Use of this uniform capacity allows direct comparisons of costs and impacts between technologies. However, this is not meant to imply that these technologies are suitable to this size of industrial boiler only. Chapter 4 and the ITAR's review the applicability of emerging technologies to other sizes of boilers.

E.2 ENVIRONMENTAL AND ENERGY IMPACTS OF EMERGING TECHNOLOGIES

This section presents a brief review of the air, liquid waste, solid waste, and energy impacts associated with the emerging technologies defined in Section E.1. As mentioned earlier, this information is, in part, based on preliminary studies of undeveloped technologies. Impacts are likely to change somewhat as the technologies mature.

E.2.1 Air Impacts

The annual air pollution impacts for each model boiler are presented in Table E-3. Annual emissions are reported for both uncontrolled and controlled boilers designed to meet emission limits detailed in Table E.1. Annual emissions are reported in Mg/yr (tons/yr) for the controlled and uncontrolled cases. The percent reduction values shown represent the reduction achieved over a conventional uncontrolled boiler. For the oil-fired boilers, the uncontrolled case is simply an oil-fired boiler without SCR control. For the boiler systems which use coal, the uncontrolled case is a conventional high sulfur coal-fired spreader stoker without emission controls.

E.2.2 Liquid Waste Impacts

There are no liquid streams associated with the SCR systems examined; however, there is one potential source of water pollution. In some

TABLE E-3. EMERGING TECHNOLOGY MODEL BOILER ANNUAL EMISSIONS

Model[a] Boiler	Emission(s) Controlled	Annual Emissions Mg/yr (tons/yr)		Emission Reduction (percent)
		Uncontrolled[b]	Controlled	
RES-150-SCR/PF	NO_x	131 (145)	13.1 (14.5)	90.0
DIS-150-SCR/FB	NO_x	78.7(86.7)	7.87 (8.67)	90.0
HSC-150-LBG	NO_x	225 (248)	71.6 (78.8)[d]	68.3
	SO_2	2040 (2247)	179 (197)[d]	91.2
	PM	2083 (2294)	10.7 (11.8)[d]	99.5
HSC-150-CLP	SO_2	2040 (2247)	916 (1009)	55.0
HSC-150-FBC	SO_2	2040 (2247)	204 (225)	90.0

[a] Model boilers and abbreviations defined in Table E-1.

[b] For oil-fired boilers, uncontrolled emissions are actual emissions prior to SCR control. For other boilers, a spreader stoker is assumed representative of uncontrolled emissions.

[c] FBC boilers typically achieve a slight (less than 20%) NO_x reduction compared to a conventional spreader stoker. However, available data is inconclusive (see Chapter 4).

[d] The controlled emissions shown are those resulting from combustion of low-Btu gas. The gasification process emits small amounts of NO_x, SO_2, and PM. In addition, other emission species (organics, CO, NH_3, HCN, H_2S, and COS) are also emitted in small amounts.

Japanese installations, NH_4HSO_4 deposits (see Chapter 4) are removed from the air preheater by water washing. The blowdown from this operation will contain both ammonium and sulfate ions which, if not treated, present a water pollution source. Since the amount of NH_4HSO_4 and water are not known, it is not possible to estimate the concentration or flow of this potential source.

There are no waste water streams directly associated with the FBC or CLP model boilers. Disposal of the solid waste from these boilers is expected to occur by landfilling. A secondary water pollution impact may exist at sites where rainfall runoff causes percolation and leaching of materials from the spent and unspent sorbent.

In a coal gasification facility, the specific sources which generate wastewaters will determine the type of contaminants that are present in those streams. Potential water effluents from a Wellman-Galusha low-Btu gasification facility include:[4]

- coal storage runoff,
- ash sluicing water,
- process condensate, and
- stretford process blowdown.

The coal storage runoff stream principally contains dissolved metals and inorganics that have been leached from coal in uncovered storage piles or bins. The quantity and composition of this stream are highly dependent on the site of the gasification facility.[5]

Ash sluice water is used to aid the removal of ash from the gasifier. This stream principally contains ash, dissolved metals, and inorganics that have been leached from the ash, but also contains some organic compounds. The composition of the ash sluice water depends, of course, on the characteristics of the gasifier ash. The only data presently available on ash sluice water composition are for gasifying anthracite coal. Those data indicate few compounds are present in hazardous concentrations. Generalizing these results to other coal types is not warranted.[5]

In cooling the raw low-Btu gas to the operating temperature and pressures of the sulfur removal processes (44°C or 137°F for Stretford processes and essentially atmospheric pressure), water is condensed and subsequently removed from the gas quenching and cooling system. This condensate contains many of the constituents of the low-Btu gas, including nitrogen species (such as NH_4^+ and CN^-), particulates (which are relatively rich in trace elements), organics (including phenols, thiols, and polynuclear aromatic hydrocarbons), and dissolved gases.[6] Numerical values for the effluent generated by the process condensate stream are reported in the synthetic fuels ITAR for various control levels.[7] For the LBG model boiler in this report, the value is 1217 Mg/yr (1340 tons/yr). This value represents the quantity of condensate sent to an on-site evaporator. Residual wastes after evaporation may be as little as 5 percent of the value reported above.

The principal pollutants found in the Stretford blowdown are thiosulfate and thiocyanate. Specific standards for the discharge of these pollutants do not exist. The effluent generated by the blowdown stream is estimated to be 500 Mg/yr (551 ton/yr).[8]

E.2.3 Solid Waste Impacts

Solid waste impacts for all emerging technology model boilers are summarized in Table E-4. All values were taken directly from the ITAR's with the exception of the coal/limestone pellet (CLP) technology. Solid waste impacts for CLP were determined partially on the basis of documentation supplied from the fluidized bed combustion (FBC) ITAR.[11] The assumptions used are presented at the end of this subsection where CLP solid waste is discussed.

The only solid waste associated with the SCR systems is the spent catalyst. The life of SCR catalysts has been estimated to be from 1-2 years.[12] However, no commercial SCR units have operated long enough to require catalyst replacement, therefore, estimates of solid waste generation are not reported. In addition, the catalysts used are expensive, making regeneration an attractive alternative to conventional disposal techniques. Regeneration would minimize the solid waste impacts of SCR.

TABLE E-4. EMERGING TECHNOLOGY MODEL BOILER ANNUAL SOLID WASTE PRODUCTION[9,10]

Model[a] Boiler	Emission(s) Controlled	Source of Solid Waste	Type of Solid Waste	Annual Solid Waste Production Mg/yr	(tons/yr)
RES-150-SCR/PF	NO_x	SCR reactor	Spent catalyst	b	
DIS-150-SCR/FB	NO_x	SCR reactor	Spent catalyst	b	
HSC-150-LBG	NO_x,SO_2,PM	Gasifier Cyclone Acid gas removal	Bottom ash Dust Sulfur cake	5441 305 2746	(5992) (336) (3024)
HSC-150-CLP	SO_2	Boiler and final PM control[c]	Bottom ash and fly ash	13104	(14431)
HSC-150-FBC	SO_2	Boiler and final PM control[c]	Bottom ash and fly ash	13221	(14538)

[a] Model boilers and abbreviations defined in Table E-1.

[b] Insufficient data to estimate catalyst replacement rates.

[c] Assuming some type of high efficiency final PM control device (uncontrolled PM emissions are unlikely to be acceptable in most instances).

Solid wastes generated by the LBG system include gasifier ash, cyclone dust, and sulfur cake. Solid waste production is considerably higher for the gasification and purification system than for an uncontrolled coal-fired boiler. The quantity of gasifier ash produced can be as much as 700 percent greater than the bottom ash from a coal-fired boiler. This is because of the higher coal throughput required for gasification to overcome the coal loss associated with the LBG process, and because some of the coal ash evolves as fly ash during combustion while most of it appears as gasifier ash in gasification.[13] Cyclone dust and sulfur cake are additional solid waste products from the gasification system not produced from uncontrolled coal-fired boilers.

The gasifier ash and sulfur cake (and possibly the cyclone dust) can be disposed of by landfill, with steps taken to prevent surface and ground water contamination from water runoff and leachate. Sulfur produced by the Stretford process is a wet cake containing about 50 percent water and 4 percent total dissolved solids. This cake contains chemicals from the Stretford solution that may be leachable from the sulfur cake. The concentration of these chemicals in the cake depends on the degree and effectiveness of cake washing. This sulfur cake could be autoclaved and further purified to produce pure molten sulfur suitable for sale, but the small quantities produced in the systems considered in this report would probably make this purification economically unattractive.[14]

The cyclone dust consists mostly of carbon which can be incinerated rather than being landfilled. In fact, under current regulations, landfill of the dust may not be allowed if it classified as a hazardous "ignitable" waste.[15]

The major adverse environmental impact of fluidized-bed combustion is expected to be the solid waste which is produces. Solid residue from the fluidized-bed process consists of a mixture of spent bed material (largely calcined and sulfated sorbent), bottom ash and fly ash collected in the particulate matter control devices. The amount of solid waste produced is a function of the fuel and sorbent characteristics. The solid waste loading reported in Table E-4 constitutes the total waste produced by the system; about 85 to 95 percent of the waste will be withdrawn as spent bed material, assuming that the material collected in the primary cyclone is recycled to the bed. The remaining 5 to 15 percent elutriates from the bed, passes through the primary cyclone, and is collected by a final particulate control device.[16] Solid waste generated by the FBC system with a fabric filter is 300 percent higher than that from a coal-fired spreader stoker using a fabric filter for fly ash collection.

Total solid waste production for CLP firing was calculated based on a pellet Ca:S molar ratio of 3.5:1. In addition, it was assumed that the limestone used was 90 percent $CaCO_3$ and 10 percent inert material and that 95 percent of the $CaCO_3$ is calcined in the bed.[17]

E.2.4 Energy Impact

Table E-5 provides data on energy usage for the emerging technology model boilers examined. Energy required to operate the emerging technologies may be in one of several forms. For SCR systems, electricity is used to drive fan motors and to pump ammonia for injection systems. For gasification systems, additional coal input is required to overcome substantial conversion losses in the gasification process. In addition, electricity is required for fans and pumps in the gasifier and emission control system. Steam is needed in the gasifier itself; this steam could be supplied from the gas-fired boiler which the gasifier feeds. For FBC boilers, the overall boiler efficiency is slightly higher than for conventional stoker boilers; thus, the coal feed for a given steam output is actually reduced. Electricity is required, however, to supply air for bed fluidization and to handle increased solids input and outputs from the boiler. The use of CLP incurs a slight energy penalty due to reduced boiler efficiency. At present, data is insufficient to estimate the magnitude of this penalty.

The gasification of coal to produce a low-Btu gas incurs a significant energy penalty. For the Wellman-Galusha/Stretford system used in the

TABLE E-5. EMERGING TECHNOLOGY MODEL BOILER ENERGY USE[18,19,20]

Model Boiler[a]	Emission(s) Controlled	Energy Use[b] Type	Amount MW	Amount (10^6Btu/hr)	Percent of Boiler Input
RES-150-SCR/PF	NO_x	Electricity	0.134	(0.458)	0.31
		Steam	0.034	(0.115)	0.08
		Total	0.168	(0.573)	0.38
DIS-150-SCR/FB	NO_x	Electricity	0.121	(0.414)	0.28
		Steam	0.0706	(0.241)	0.16
		Total	0.192	(0.655)	0.44
HSC-150-LBG	NO_x,SO_2,PM	Coal Feed	18.3	(62.5)	41.6
		Electricity	2.5	(8.4)	5.6
		Steam	0.15	(0.5)	0.3
		Total	20.9	(71.4)	47.5
HSC-150-CLP	SO_2	Insufficient Data			
HSC-150-FBC[c,d]	SO_2	Coal Feed	-0.96	(-3.28)	-2.2
		Electricity	0.47	(1.60)	1.1
		Total	-0.49	(-1.68)	-1.1

[a] Model boilers and abbreviations defined in Table E-1.

[b] Negative numbers indicate net decrease in energy use.

[c] For FBC control technique, energy use shown is net increase or decrease compared to conventional spreader stoker.

[d] Energy use of final PM control device not included.

model boiler analysis, an energy penalty of approximately 48 percent is incurred to gasify high sulfur coal. The major contributor to the energy consumed by the low-Btu gasification system is the gasification inefficiency. This includes both conversion losses and the energy content of the by-product tars and oils. Use of the by-products' energy would lower the energy penalties presented by about 20 percentage points.[21]

E.3 COSTS OF EMERGING TECHNOLOGY CONTROL TECHNIQUES

This section presents an analysis of the costs associated with using emerging technology emission control techniques. This cost analysis is intended to provide a comparative analysis to allow the general assessment of the costs of using the emerging technologies. Since emerging technologies are, by definition, still under development, these costs should be considered as approximate and are likely to change considerably as the technologies mature.

For the most part, the costs presented are developed from costs presented in the Individual Technology Assessment Reports (ITAR's). For coal/limestone pellets, no such report is available. In this case, costs were developed by integrating data from the coal/limestone pellet supplier with the engineering data from Chapter 4.[22]

Both capital and annualized cost impacts are presented for each emerging technology (in June 1978 dollars). These costs are developed for both boiler and emission control(s) systems. The cost bases (i.e. fuel costs, labor rates, interest rate, etc.) are essentially unchanged from those used to cost the model boilers in Chapter 8.

E.3.1 Analysis of Capital Cost Impacts

Table E-6 presents the capital costs for the five emerging technology model boilers. Of immediate note is the disparity between capital costs of oil- and coal-fired boilers. In general, oil-fired units cost have significantly lower capital costs.

The capital costs of the residual oil- and distillate oil-fired emerging technology model boilers are virtually equivalent. The higher costs of the parallel flow SCR system compared to the fixed bed system

TABLE E-6. CAPITAL COSTS OF EMERGING TECHNOLOGY MODEL BOILERS ($1978)[22]

Model[a] Boiler	Emission(s) Controlled	Emission[b] Reduction(s) (percent)	Capital Costs ($1000) Boiler Cost	Capital Costs ($1000) Control Cost	Capital Costs ($1000) Total Cost
RES-150-SCR/PF	NO_x	90.0	2735	502	3244
DIS-150-SCR/FB	NO_x	90.0	2927	311	3238
HSC-150-LBG	NO_x SO_2 PM	68.3 91.2 99.5	1860[d]	10911[e]	12771
HSC-150-CLP	SO_2	55.0	8971	w/boiler	8971
HSC-150-FBC	SO_x[c]	90.0	9921	w/boiler	9921

[a] Model boilers and abbreviations defined in Table E-1.

[b] For oil-fired boilers (RES-150, DIS-150) the reductions listed are actual reductions achieved by the SCR control device. Other model boilers use control techniques which are inherent in the boiler or the fuel preparation prior to the boiler. For these cases, emission reductions are relative to an uncontrolled spreader stoker firing high sulfur coal.

[c] FBC boilers typically achieve a slight (less than 20%) NO_x reduction compared to an uncontrolled spreader stoker, however, available data is inconclusive (see Chapter 4).

[d] Low-Btu gas-fired boiler.

[e] Gasifier and emission controls required for gasifier.

are offset by the higher boiler capital cost for the uncontrolled distillate-fired unit compared to the residual-fired unit (primarily due to higher working capital costs for distillate fuel). The most capital intensive emerging technology is LBG. For the coal-fired boilers, the total capital cost of the boiler and gasifier system is considerably more expensive than all other control technologies examined. Most of the gasifier cost (85 percent) is associated with the extensive air and water pollution controls on the gasifier itself.

E.3.2 Analysis of Annualized Cost Impacts

Table E-7 presents the annualized costs for the five emerging technology model boilers. Figure E-1 illustrates the "normalized" total annualized costs of boilers and controls. The normalized cost is calculated by dividing the annualized cost by the total annual heat input to the boiler. Any comparisons between these costs should keep in mind the different emissions species under control and the relative levels. LBG, for example, is the most expensive technique examined. However, it is the only technology examined which achieves comparatively large decreases in all three major emission species.

For annualized as well as capital cost, the LBG model boiler is the most expensive model boiler examined. In fact, the normalized annual cost of the LBG model boiler exceeds the costs of all coal-fired model boilers examined in Chapter 8.

The FBC and CLP technology costs are roughly equivalent. The CLP technology has a small three percent cost advantage. However, it should be noted that the CLP technology is considerably less advanced than the FBC technology. Further experience with CLP-firing may indicate lower achievable SO_2 removal and/or higher pelletizing costs.

TABLE E-7. ANNUALIZED COSTS OF EMERGING TECHNOLOGY MODEL BOILERS ($1978)[22]

Model[a] Boiler	Emission(s) Controlled	Emission[b] Reduction(s) (percent)	Annualized Cost ($1000/yr) Boiler Cost	Control Cost	Total Cost	Normalized[f] Total Cost
RES-150-SCR/PF	NO_x	90.0	4368	226	4626	6.41
DIS-150-SCR/FB	NO_x	90.0	5260	208	5468	7.57
HSC-150-LBG	NO_x SO_2 PM	68.3 91.2 99.5	6598[d]	5718[e]	6598	8.36
HSC-150-CLP	SO_2	55.0	4436	w/boiler	4436	5.63
HSC-150-FBC	SO_2	90.0[c]	4592	w/boiler	4592	5.82

[a] Model boilers and abbreviations defined in Table E-1.

[b] For oil-fired boilers (RES-150, DIS-150) the reductions listed are actual reductions achieved by the SCR control device. Other model boilers use control techniques which are inherent in the boiler or the fuel preparation prior to the boiler. For these cases, emission reductions are relative to an uncontrolled spreader stoker firing high sulfur coal.

[c] FBC boilers typically effect a slight (less than 20%) NO_x reduction compared to an uncontrolled spreader stoker, however, available data is inconclusive (see Chapter 4).

[d] Includes cost of gasification.

[e] Cost of gasification process and emission controls.

[f] Total annualized cost divided by annual heat input ($/$10^6$Btu).

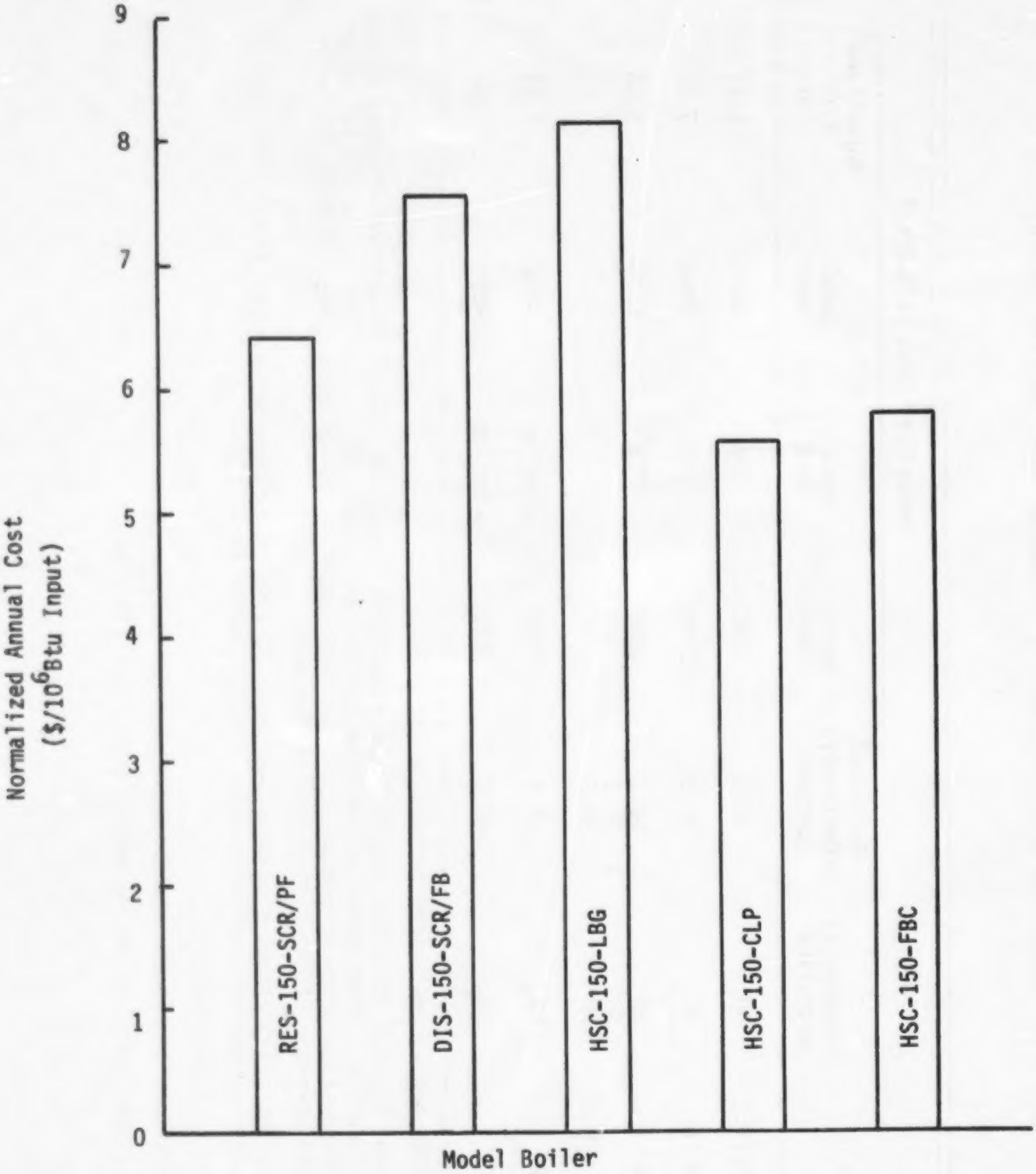

Figure E-1. Annualized costs of emerging technology model boilers.

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4. Reference 2, p. 6-8.

5. Reference 2, pp. 6-14, 6-15.

6. Reference 2, p. 6-15.

7. Reference 2, p. 6-9.

8. Reference 2, p. 6-9.

9. Reference 2, p. 6-20.

10. Reference 3, p. 364.

11. Reference 3, pp. 360-366.

12. Reference 1, p. 6-24.

13. Reference 2, pp. 6-19, 6-21.

14. Reference 2, p. 6-22.

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16. Reference 3, p. 361.

17. Piccot, S.P. "Solid Waste and Fuel Feed Calculations for Coal/Limestone Pellet Technology Model Boiler". Memo to Industrial Boiler File. Radian Corporation.

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